ELECTRICAL ENGINEERING

APRIL 1950

NORTH EASTERN DISTRICT MEETING, PROVIDENCE, R. I., APRIL 26-28, 1950

Mechanically
Trip-Free
Operator

Standard

..ON ALL ALLIS-CHALMERS PNEUMATICALLY OPERATED POWER OIL CIRCUIT BREAKERS

INSTANT BREAKER OPERATION UNDER ALL FAULT CONDITIONS!

MECHANICALLY TRIP-FREE action instantly releases contacts from closing force when closed on a fault . . . permits high contact acceleration *unhindered by closing cylinder back-pressure or toggle inertia* on pneumatically operated breakers. You get instant, complete contact opening under all tripping conditions.

With this Allis-Chalmers electro-pneumatic operator, highest possible system stability and service continuity are maintained. The breaker cannot be held closed on a fault . . . and operator mechanism is quickly recoupled to permit fast reclosing — within 20 cycles. Pneumatic operation furnishes reliable, high speed contact closing — requires only fractional horsepower motor.

This mechanically trip-free operator is just one of many standard features you get on Allis-Chalmers oil circuit breakers. For details on any rating, contact your nearby A-C representative. Or write direct.

ALLIS-CHALMERS, 931A SO. 70 ST.
MILWAUKEE, WIS.

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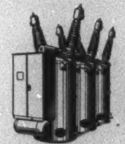
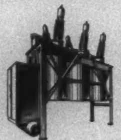
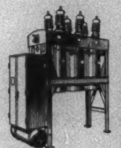
IT'S STANDARD EQUIPMENT ON THESE ALLIS-CHALMERS OIL CIRCUIT BREAKERS


TYPE BZO-160 . . . from 69 to 230 kv — 3 or 5-cycle opening, 20-cycle reclosing.


TYPE FZO-151 . . . 69kv . . . frame-mounted—5 or 8 cycle opening, 20-cycle reclosing.


TYPE FZO-150 Unitop . . . 15 to 46 kv — 8-cycle opening, 20-cycle reclosing.

Unitop is an Allis-Chalmers trademark.

ALLIS-CHALMERS

A-C ALLIS-CHALMERS

Pioneers in Power and Electrical Equipment From Generation Through Utilization

ELECTRICAL ENGINEERING

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APRIL
1950

The Cover: Two-unit 4,000-horsepower diesel-electric locomotive in passenger service on the New York, New Haven and Hartford Railroad which is one of the leading roads in the use of diesel motive power.

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2+2=99,999,999!

YES, 2 plus 2 *can* equal 99,999,999, if a vital spring fails in an adding or computing machine. And a broken spring can cause much more subtle errors which are hard to detect. The machine may operate correctly for weeks, then suddenly insert small (or large) errors which will completely upset an involved operation.

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UNITED STATES STEEL

HIGHLIGHTS........

Why Go the Way of Britain? The question is propounded by Sir Ernest Benn—a Briton who deplores the present socialistic trends in his country. He points out that the real issue is a moral one of individualism versus collectivism and reminds us that America herself is about half-way down the road toward complete State control (*pages 293–5*).

Engineering the Economic Future. Citing Great Britain's economic difficulties under a Labor Government as an example, Harold Stassen stresses the importance of the principle of incentive (and, conversely, penalty) for productive effort in the success of any economic system. This principle is a fundamental part of our own system of free enterprise and Americans must recognize the necessity for preserving it "if we are to contribute to the future liberty of the world and are to raise the standard of living of peoples everywhere" (*pages 296–9*).

New Lightning Arrester Standard. For the past several years there have been three separate AIEE Standards relating to the lightning protective devices field. These now have been combined into one Standard, AIEE *28A*, "Lightning Arrester Standards for Valve and Expulsion Arresters" (*pages 359–60*).

Air-Core Reactors. The use of air-core reactors for motor branch circuits in conjunction with high interrupting capacity controllers is discussed in this article. Two important limiting factors in such use, that is, their increase in size and weight and the reduction in voltage at the motor during starting, are considered also (*pages 329–33*).

Conference Paper Digests. On April 5–7 the AIEE Conference on Electric Welding will be held in Detroit, Mich., while the AIEE Power Conference will meet in Pittsburgh, Pa., April 19–20. Brief authors' digests of most of the papers to be presented at both of these conferences are included in this issue (*pages 361–3; pages 363–4*).

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Transient Performance of D-C Machinery. The question of transient characteristics in d-c rotating machinery and the effect of these transients on system operation has long been of interest to Navy engineers, because of the extensive use of direct current aboard ship. A thorough study of external and internal phenomena of machines under all conditions has been made (*pages 301–05*).

Relay Protection for Transmission Lines. A wide selection of protective relaying equipment has been developed over the years; it varies from simple instantaneous current relays to directional and impedance-type relays. The most efficient installations of these relays on a typical medium-length high-voltage transmission line are described this month (*page 314–19*).

Transient and Steady-State Concepts. The viewpoint that steady-state and transient concepts are reciprocally related is put forth in an article by W. J. Kessler. Traditionally, transient concepts are applicable during the sudden application or removal of driving forces of voltages, and steady-state concepts are applicable when the transient characteristics are negligible. However, this article shows the reciprocal relationship between them (*pages 319–21*).

Synchronous Air-Borne Camera System. A camera motor control system has been developed to take 20 frames of movie film per second and keep the cameras synchronized to within ±0.002 second. The driving system uses pulses from a 1,200-rpm shaft to synchronize series d-c motors running at 3,600 rpm. A second group of cameras in a remote aircraft can be operated by radio signals from the parent aircraft (*pages 324–7*).

Transients and Feedback in Magnetic Amplifiers. Presented this month is an article analyzing the steady-state and transient characteristics of the magnetic amplifier without feedback, with external feedback, and with one commonly used type of feedback. Experimental data are presented to show the accuracy to be expected from the formulas which are developed (*page 353–9*).

Effect of Deionization Time on Reclosing Circuit Breakers. Formerly, the time required to resume service after a fault interruption was determined by the time needed to reclose the circuit breaker. Now, however, the reclosing time has been reduced so much that the time for a successful reclosure is determined by the arc deionization time (*pages 346–50*).

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions.*

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (EE, *Dec '46, pp 567–8*; *Jan'47, pp 82–3*). They are available to AIEE Student members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Dec '48, p 35A	Midwest General Southern District
Apr '49, p 25A	Winter General (1949)
Jul '49, p 47A	South West District Summer General
Nov '49, p 51A	Pacific General Fall General
Feb '50, p 46A	Winter General (1950)

Measuring Thickness With Beta Rays. A new "gauge" for measuring thickness of materials is the beta particle. By interposing the sample between a source of beta radiation and an ionization chamber, the dimensions of the material can be determined. Advantage of this method is that no physical contact with the sample is required (*pages 308–10*).

Two-Channel Carrier Telegraph System. The new 2-channel carrier telegraph system installed by Western Union between Key West and Havana is described by E. L. Newell and C. H. Cramer. The line uses standard frequency-modulation channel terminal equipment and has attenuations up to 80 decibels at 1,000 cycles per second over its 100 miles (*pages 338–42*).

Correction. Through an oversight, the membership affiliation of J. Steinberg (Fellow AIEE) was omitted when his article, "Relation of Plant Design to Reserve Capacity," was published in *Electrical Engineering* (*EE, Jan '50, pp 64–7*). Also, in connection with the publication of "Protective Covering for Lead Sheath Power Cables" (*EE, Mar '50, pp 223–5*), the professional affiliation of C. T. Nicholson was given incorrectly as the Rochester Gas and Electric Corporation. The correct affiliation is the Niagara Mohawk Power Corporation.

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STANDARD RI-FI* METERS

14kc *to* 1000mc!

DEVELOPED BY **STODDART**
FOR THE ARMED FORCES.
AVAILABLE COMMERCIALLY.

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15 MC
to
400 MC

NMA - 5

Commercial equivalent of TS-587/U. Sensitivity as two-terminal voltmeter, (95 ohms balanced) 2 microvolts 15-125 MC; 5 microvolts 88-400 MC. Field intensity measurements using calibrated dipole. Frequency range includes FM and TV Bands.

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250 KC

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Commercial equivalent of AN/URM-6. A new achievement in sensitivity! Field intensity measurements, 1 microvolt-per-meter using rod; 10 microvolts-per-meter using shielded directive loop. As two-terminal voltmeter, 1 microvolt.

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to
1000 MC

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Commercial equivalent of AN/URM-17. Sensitivity as two-terminal voltmeter, (50-ohm coaxial input) 10 microvolts. Field intensity measurements using calibrated dipole. Frequency range includes Citizens Band and UHF color TV Band.

Since 1944 Stoddart RI-FI* instruments have established the standard for superior quality and unexcelled performance. These instruments fully comply with test equipment requirements of such radio interference specifications as JAN-I-225, ASA C63.2, 16E4(SHIPS), AN-I-24a, AN-I-42, AN-I-27a, AN-I-40 and others. Many of these specifications were written or revised to the standards of performance demonstrated in Stoddart equipment.

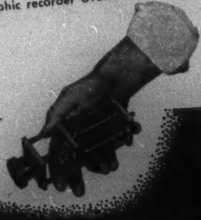
The rugged and reliable instruments illustrated above serve equally well in field or laboratory. Individually calibrated for consistent results using internal standard of reference. Meter scales marked in microvolts and DB above one microvolt. Function selector enables measurement of sinusoidal or complex waveforms, giving average, peak or quasi-peak values. Accessories provide means for measuring either conducted or radiated r.f. voltages. Graphic recorder available.

***Radio Interference and Field Intensity.**

Precision Attenuation for UHF!

Less than 1.2 VSWR to 3000 MC.
Turret Attenuator:
0, 10, 20, 30, 40, 50 DB.
Accuracy ± .5 DB.

Patents applied for.



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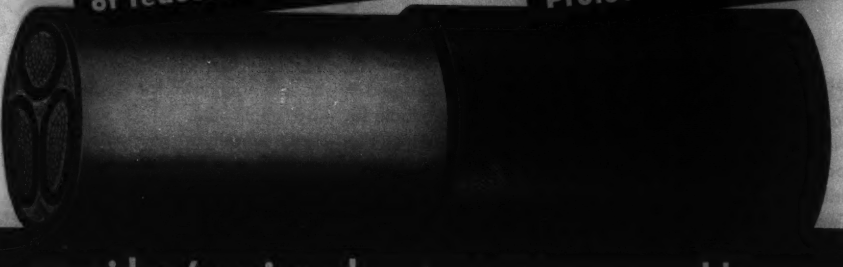
HOW OKOMETAL of reduced thickness PLUS OKOSHEATH Protective Covering



...provides 6 major advantages to paper cable users

*** A story so important that it will be developed in two successive issues of this magazine.**

Okometal of reduced thickness plus Okosheath Protective Covering is the latest improvement in paper cable sheathing produced by Okonite-Callender Research Laboratories. The result of long, intensive study and testing, it is a composite sheath of alloyed lead protected by a tough, reinforced neoprene covering vulcanized and firmly bonded to the lead. This dual sheath provides *six major advantages* to a growing list of users. Here are three of the advantages you get with Okometal-Okosheath cable construction:

Doubled Cable Life Expectancy: Dummy manhole-bending machine tests show that Okometal — a lead alloy developed by the Okonite-Callender Research Laboratories — doubles service life expectancy through increased resistance to bending fatigue at joint offsets in manholes. This doubled resistance permits the use of reduced lead thicknesses up to one-third less than standard when the Okosheath Protective Covering is employed.

DUMMY MANHOLE TEST: Completed cables with joints, trained to standard contours are subjected to ½" movement at 4-minute cycles at actual operating temperatures. In this, and similar power company tests, 270 bending cycles are equal to about 1 year actual service. Cables with Okometal-Okosheath Protective Covering outlast plain lead-covered cables 2⅔ to 1.

Elimination of Corrosion: For over 15 years our Okosheath Protective Covering has been used by power companies to eliminate chemical, electrolytic and galvanic corrosion of lead sheaths. There is no recorded instance where lead sheath corrosion has occurred in cables protected by Okosheath. Extensive laboratory, field and service tests yield convincing evidence of its complete resistance to corrosion.

Reduced Installation and Maintenance Costs: In addition to reducing the number of manholes and joints through lighter weight and a lower co-efficient of friction, this Okometal-Okosheath combination promotes further economies through eliminating the costly practice of grading and flushing duct lines. Longer cable life and doubled resistance to failure also contribute to reduced maintenance costs.

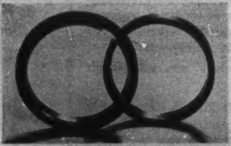
• • •

In the next issue of this magazine we will discuss these remaining important advantages of Okometal-Okosheath cable construction:

GREATER BURSTING STRENGTH • PREVENTION OF LEAD SCORING

EASIER PULLING

Meanwhile, comparative test results, explanatory photographs and diagrams, as well as more detailed information of this important development are available in Research Publication EG-1047. Write for your copy on your business letterhead. The Okonite Company, Passaic, N. J.



Compare this substantial dual construction with plain lead of same core diameter.

Okonite-Callender cables with this composite sheath meet all AEIC Test requirements for paper cables with plain lead of standard thickness.

7033

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NOW!

4500 amperes POWER FUSE protection for $11.60
6900 amperes POWER FUSE protection for 16.80
8600 amperes POWER FUSE protection for 20.25

Can you

PRICES ARE WAY DOWN — on S&C Liquid Power Fuse equipment for 7,500- and 15,000-volt installation, making its dependable performance available for wider application.

Now there is no need to gamble on cutouts where high short-circuit currents are available. Nor is there need to pay a heavy premium over cutout prices to get reliable power fuse protection for 6,900- to 13,800-volt distribution transformer and substation installations.

Two innovations have made the advantages of the Liquid Power Fuse available at the new low prices shown below: (a) The new Simplified Mounting, pictured and described here, which is better, yet cheaper, than the conventional switch insulator type mounting it replaces and, (b) a new plan for the purchase of Liquid Fuses which reduces prices and does away with the need for returning blown fuses to the factory for refill.

Comparison of interrupting ratings and costs① of the Liquid Fuse with other typical protective devices follow:

	Ordinary Open Drop-Out Cutouts		Drop-Out Power Fuses				Liquid Power Fuses With Simplified Mounting			
			Expulsion Type Using			Solid Material Type				
			Fuse Link		Fuse Unit					
Ampere Rating Range	To 100E	100E to 200E	To 100E	100E to 200E	½-125E	½-200E	1-10E (Size 1)	10-20E (Size 2)	½-50E (Size 3)	½-125E (Size 4)
	7500 VOLTS									
Interrupting Ratings in amperes, rms, asymmetrical	2000	4000	4000	6000	5000	12,000	4500	4500	6900	8600
First Cost②	$13.75	$21.30	$44.38	$44.92	$44.50	$54.00	$11.60	$12.45	$16.80	$20.25
20-Year Equipment Cost③	14.02	22.11	45.14	46.00	47.80	57.60	13.34	14.70	21.00	26.25
	15,000 VOLTS									
Interrupting Ratings in amperes, rms, asymmetrical	2000	4000	4000	6000	8000	11,000	3900	3900	5900	7400
First Cost②	$16.95	$26.13	$47.46	$48.00	$47.50	$60.50	$12.95	$14.45	$18.80	$22.95
20-Year Equipment Cost③	17.22	26.94	48.22	49.08	50.80	64.40	15.05	17.75	23.75	30.15

① Costs computed from prices in effect September 1949, using maximum discount quantities.

② Includes mounting and fuse, fuse link, refill unit, or fuse unit.

③ First cost plus 20-year cost of re-fusing.

DESIGNED FOR

FULL COVERAGE

FULL COVERAGE FUSING IS: the new concept of transformer fusing in which a primary fuse is applied for both primary short circuit and secondary back-up short circuit protection.

FULL COVERAGE FUSING PROVIDES—in addition to primary short circuit and secondary back-up short circuit protection—savings in operating expense by:

(1) Eliminating the need for replacement of "suspect" fuses, links, or refills on other phases when one fuse blows.
(2) Eliminating the need for periodic replacement of fuses, links, or refills to prevent "sneak-outs" caused by vibration- or age-weakened fusible elements.
(3) Eliminating "sneak-outs" caused by high current surges.

FULL COVERAGE FUSING REQUIRES: dependable high and low fault-current interrupting ability; a fine degree of accuracy in time-current characteristics; a "non-damageable" fusible element which cannot be injured by surge currents, vibration, or aging; and a full range of speeds—standard, slow, and time-lag—to provide flexibility in coordinating with other primary, and with the secondary, protective devices.

OTHER BENEFITS YOU GET WITH S&C LIQUID POWER FUSES:

1. **Short Arcing Time**—Shortest of any power fuse or cutout.
2. **No Interference from Sleet or Glaze**—because drop out action not needed to prevent tracking or to indicate a blown fuse.
3. **All Low Fault Currents Cleared**—unlike expulsion type devices, Liquid Fuses clear all types of low fault currents dependably.
4. **Stable Time-Current Characteristics**—achieved through S&C "Non-Damageable Fusible Element Construction", permit close, permanent, coordination; and eliminate "sneak-outs" (unnecessary outages).
5. **Fire Hazard Minimized**—no hot metal ejected to cause grass or underbrush fires.

S&C ELECTRIC

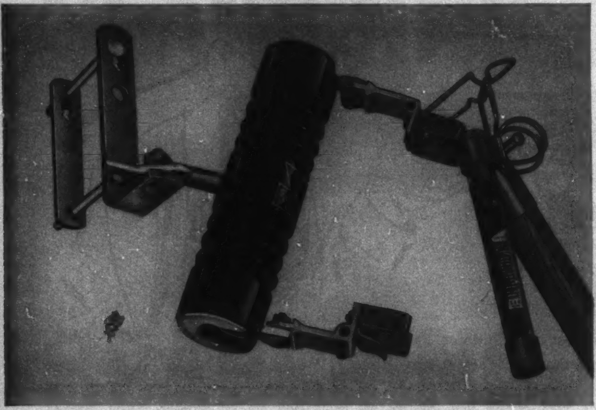
Formerly SCHWEITZER & CONRAD, INC.

longer afford to gamble on —

cutouts to protect investment and service continuity where high fault currents are possible?

NEW SIMPLIFIED MOUNTING FOR S&C LIQUID POWER FUSES

One reason for the low prices of this fuse and mounting combination is the new Simplified Mounting. As shown by the illustration, it is smaller and lighter than other type mountings. Yet streamlining has actually improved its insulation values by increasing leakage distances and flashover characteristics. In fact, its insulation values greatly exceed NEMA Standards for cutouts, and equal NEMA Standards for switch and bus insulators.



7,500-volt, 20E-ampere, Size 2 Liquid Power Fuse and Simplified Mounting. Total cost of mounting, hanger, fuse and clips—$12.45. Interrupting rating—4500 amperes.

Its first cost is lower. Its installation costs are lower.

It is bird- and animal-proof because the mounting bracket is located on the opposite side of the insulator from the live parts.

A NEMA Standard hanger and adjustable mounting bracket provide exceptional flexibility in positioning on cross arm, pole, or structure.

New fuse clips provide easy fuse handling with any ordinary hook stick.

Write today for full information given in new Catalog Section 223.

NEW NON-EXCHANGE PLAN FOR PURCHASE OF S&C LIQUID POWER FUSES

Another reason for the low prices of this new fuse and mounting combination is the reduction in costs made possible by the elimination of factory refilling of S&C Liquid Fuses. This can be done now under an alternative purchasing arrangement known as the Non-Exchange Plan.

This plan will be a money saver for most users of type B, COR, and D Liquid Fuses (of any voltage or size). Ask your S&C Representative for details, or write the factory.

COMPANY

4427 Ravenswood Avenue
Chicago 40, Illinois, U. S. A.

IN CANADA Powerlite DEVICES LIMITED, TORONTO •

Doesn't preformed strand cost a lot more?

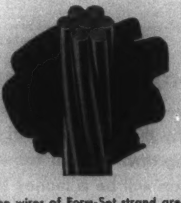
Not Bethlehem Form-Set. You pay hardly anything extra.

Buyers are often surprised at the moderate cost of Bethlehem Form-Set strand. It's preformed, yet costs so *little* more than ordinary strand—the non-preformed kind. The extra charge is almost nothing.

For a trifle more the user gains substantial advantages. Form-Set strand is easier to handle, easier to insert in fittings. The wires, through preforming, have been relieved of internal tension; hence, when cut, they all lie quietly in place. There's no explosiveness, no "bushing out" at the ends.

Try this test yourself. Using a sharp instrument, cut cleanly through an unseized length of Form-Set strand. To make the test even more convincing, use the high-strength or extra-high-strength grade. You'll find that the strand doesn't unravel or tend to loosen up. Each and every wire stays snugly in position, even at the spot where the cut has been made.

This means a lot to your linemen. Saves them time, assures a better job. For full details, ask a Bethlehem man to call.



The wires of Form-Set strand are protected against corrosion by the bethanized coating—an armor of highly-pure zinc applied electrolytically. This coating is available in three different weights.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation
Export Distributor: Bethlehem Steel Export Corporation

★ BETHLEHEM STEEL ★

SEARCHING for the perfect lead holder?

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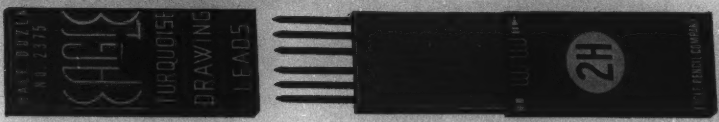
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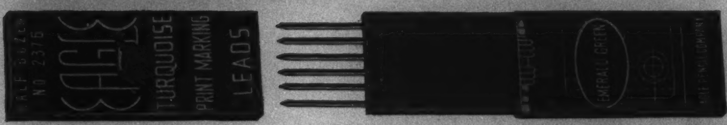
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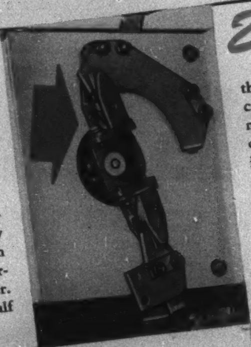
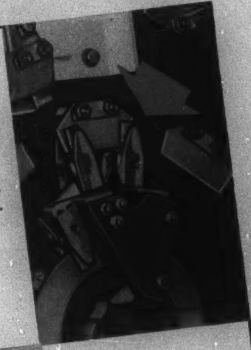
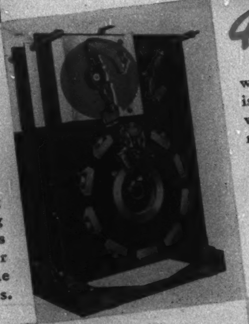
1 Arcing duty is confined to but *four* moving contacts and *two* stationary contacts per phase, through use of a separate Load Transfer Switch. Current is actually interrupted on but one moving and one stationary contact per phase in changing from one operating position to another. Photo shows front half of switch.



2 No arcing duty is imposed upon any of these Tap Selector Switch contacts, avoiding the necessity for replacement due to burning or scording. Contacts are of hardened *copper alloy* to minimize frictional wear.



3 Greatly improved arc interrupting ability is provided through use of a separate Load Transfer Switch instead of the usual single switch arrangement which performs the dual function of breaking current and changing taps. The fewer contacts of the Load Transfer Switch make possible longer arc clearances.



4 Arcing is confined to a small area in contrast with the large area which is subjected to arcing on voltage regulating apparatus incorporating a single switch for breaking current as well as changing taps.

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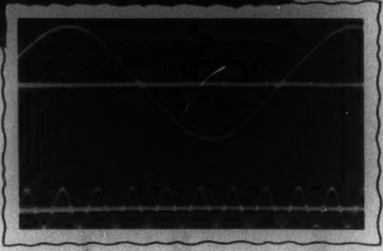

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GENERAL ELECTRIC

Why Go the Way of Britain?

SIR ERNEST BENN

In an address presented in absentia at the AIEE Winter General Meeting (and prior to the recent English elections), an Englishman descries the effects of five years of Socialistic government in Britain—and warns the United States of the folly of proceeding down the same road toward state control.

I TAKE IT as a very high honor to be invited to address so important and responsible a body as the AIEE, although I could have wished for a more congenial subject than socialistic trends in Britain as they affect America.

Even if my personal circumstances had permitted me to accept the AIEE's generous invitation to attend the Winter General Meeting in person and enjoy a few hours in the society of a body of free men, I should have felt impelled to decline, for I am not prepared to accept the only terms on which my Government will allow me to travel. I have, in the past, enjoyed my full share of what I regard as one of the happiest things on earth, the American genius for hospitality, but I have always been able to meet it on more or less equal terms. I could, for instance, offer a handful of roses or a box of candy, at my own expense, to a charming hostess. Now I can only come as a pauper, possessed it is true of a sufficiency of devalued English paper pounds, but absolutely barred from securing, of my own right, the dollars or dimes to spend as I myself would like. Being, perhaps, a pig-headed Victorian, having spent three-quarters of a century in another atmosphere, I am not prepared to put myself into this curious and uncomfortable position. Furthermore, I was able on occasion, when Americans visited England, to offer hospitality in a typical English home, which is now far too big for an Englishman to try to maintain in present conditions.

There is an alternative. Were I willing to join some official delegation for the purpose of setting up an International Authority to control, let us say, the vagaries of the magnetic pole, I could fly to and fro across the Atlantic, enjoy a life of luxury and do my full share in discovering new grounds for new squabbling between the peaceful nations of the world. I blush to think of the large numbers of my fellow countrymen who are battening on the American tax payer, to no more sensible or useful purpose than I have suggested.

What the planners have done to currency and monetary exchange illustrates perhaps better than anything else what is happening to every other commodity and service that crosses national barriers. Here I come to my main subject, for while the fortunate Americans will last a little longer than the rest of us, their doom is assuredly sealed if they, like us, rely upon politics and collective action to relieve them of the normal and natural responsibilities of healthy men.

SOCIALISM IN PRACTICE

SOCIALISM is not a system, it is a disease, and we English have at long last discovered that indubitable truth. The "something for nothing" mentality is, as we now know, an economic cancer. England, "this other Eden, demi-paradise, this blessed spot, this happy breed of men," is in a very poor way. We have suffered nearly five years of effective Socialist government, but that is only the end of the story, for we are just completing 50 years of a sloppy sentimentalism in public affairs of which the present Socialism is merely the logical outcome. In the result we have murdered old virtues with new deals. Well-meaning, shallow-thinking, kindly people, aware of the scriptural injunction that "the greatest of these is Charity," have failed to notice the distinction between the real article and the giving away of other people's money. So we come to the end of the story, having lost our faith, accepted false hopes, and practiced a charity which is nothing of the kind.

At the end of Victoria's reign, now almost exactly 50 years ago, we in this little Island, able by ourselves to grow no more than half the food we required to keep us alive, did achieve, notwithstanding its many shortcomings and blemishes, a higher general standard of living than in any country at any time, not excepting the United States of America. From that proud position we have now descended to the point where American tourists coming to visit Europe go to the countries which were conquered by Hitler in order to escape the drab austerity of Utopian Britain.

Now, at long last, I think it may be said with confidence that we have learned our lesson, learned it at an awful price, and you will rejoice with us as the peoples of the British Empire led by gallant little New Zealand, next by Australia, and in a few weeks or months time by the Home Country itself, begin on a new and very painful start to set up old John Bull once again at the service of mankind.

I understand that in the United States there are still those who think that the machinery of government can be used as a substitute for personal responsibility on the part of the governed. Shakespeare was not deceived in this way, for he said "security is mortals' chiefest enemy."

Full text of an address presented at a general session held during the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. In the absence of the author, the address was heard via a recording.

Sir Ernest Benn is Chairman of the Board, Benn Brothers, Ltd., London, England.

We have had enough experience of security to know exactly what it means: a technical claim upon salaries or wages; austerity rations bought with Marshall Aid; more and more paper money and less and less of anything to buy. The absence of the natural penalty for failure to do one's duty has reduced output per man, with glorious minority exceptions, of course, to the lowest in all our history. Our people have believed the promises of 1945 and have concentrated on their supposed rights and forgotten their responsibilities.

I repeat that I think that we are approaching very near to the end of this very painful story. There are now few thinking people among us who do not realize that while it is easy to make the rich poor, it is quite another matter to make the poor rich. One simple figure will indicate the lengths to which we have gone. Our latest tax returns show only 70 persons resident on this Island with a net spendable income of 6,000 pounds or over. The numbers of the rich have been declining for many years, but ten years ago there were still 7,000 who had this amount of money at their own disposition; 100 times as many as in 1948.

The decline still goes on, and it is probably true today, taking into account the lower value of the pound, that only one in a million English subjects is able to spend $10,000 a year for his own purposes. You can work these figures out in terms of the income and population of the United States, and imagine what it would mean to American industry and commerce and the enjoyment of the normal life of a free people.

There is little purpose to be served in dwelling on details of life, and especially business life, in the Old Country in today's circumstances. The reader will be more interested in the longer view and the lessons which are to be learned from it.

In the short period of but 50 years we have traveled the whole road, starting when no government had anything whatsoever to do with trade, and ending where all trade is under the dead hand of the State. America, I understand, is about half way along this disastrous road. To argue about taxes, pensions, houses, or even groundnuts is to scratch the surface. What has happened is the triumph of the producer over the consumer, and it proves to be an empty triumph. It is no accident which expresses the law of supply and demand in that way, supply first, demand second. Socialism in practice attempts to change the order, the theory being that one can ascertain and measure demand and then proceed to plan and organize supply. The theory ignores completely the forces which govern the ordinary actions of the ordinary man. Nature requires that the maker shall produce his goods and display them for the inspection of the buyer who is, at all times, free to decline to buy. The right to buy or not to buy is vital to economic well-being and to personal liberty. Supply and demand, in that order, put the producer in his proper place.

Among the many disasters resulting from the attempt to reverse the natural order I put, at the top of the list, the loss of the market, for we have no such thing that counts for very much in England today. The willing buyer and the willing seller have, for practical purposes, disappeared. Bulk buying, fixed prices, subsidies, and purchase taxes have abolished willingness and substituted force. Good will is a thing of the past. Price, properly so called, the result of a compromise between the willing buyer and the willing seller, is now nothing more than an official abstraction arrived at for political rather than economic reasons. The word "willing" is not to be found in any official vocabulary, and whereas a few years ago in every city and village in the world there was a measure of good will or willingness for the buyers and sellers of Great Britain, now every country is full of grievance at the real or supposed iniquities of official bargainers.

REJECTION OF BASIC PRINCIPLES

"The sanctity of contract" is a thing of the past—and that again shows how far we have departed from the principles upon which civilization was constructed. It is not merely that authorities and governments set so little value on their pledged word, however, but that no government, no authority, can ever bind its successors to take a loss.

Perhaps the biggest of all changes in this relation is the destruction of the price mechanism. Before the politicians usurped the right of the citizen to provide for himself, the price mechanism indicated with speed and certainty the existence of plenty at any time and in any place and scarcity elsewhere. It did not require committees of experts and official inquirers to discover the trends of production and consumption, and the need for adjusting action accordingly. The price mechanism has been put so completely out of action that we now are forced to pay a series of varying prices for the same article at the same time.

The natural process named by economists the "law of supply and demand" has ensured to the free citizen that freedom of choice essential to the worth-while life. Socialism tries to put the matter the other way around and to operate what is, in effect, the "law of demand and supply." Some authority claiming to know what the people want announces its intention of purchasing vast quantities of goods. Having, supposedly, an assured market, this authority is under no obligation to do its best nor to go out of its way to study the requirements of the buyers or demanders. As only one illustration, cottages or houses in England now cost five times as much as they did a few years ago, and they are not nearly as well built. It is not a question of building for the rich, but of workers building for workers, and yet with the State in between it does not work out.

Of all the false thinking of recent years in England, and I believe to some extent in America also, there is none greater than that which thinks of a job in terms of wages rather than in terms of the work done and the quality achieved.

These are general considerations, proper subjects for argument at any time in the last few decades. It is only now after an expensive and destructive war that we are beginning to reap the results of wrong thinking. Millions of our people look to the Government as their fathers of

Victorian times looked to God; with large masses of them political authority has taken the place of Heavenly guidance. In consequence here, and indeed all over the world, but here in England more than elsewhere, mankind is living by permission. That is a system which may be suited possibly to Slavs and Huns, but which is the very antithesis of the spirit of all those who speak the English language.

Herbert Spencer in that wonderful prophecy, "The Man Versus the State," explained in detail what would happen and foretold with exactitude the present rush of weaklings for jobs as planners and permitters, telling other people what not to do.

You will have noticed the curious circumstance that while we are all under the thumb of authority, authority itself is composed of those who, lacking the courage to stand upon their own feet and accept their share of personal responsibility, seek the safety of official positions where they escape the consequences of error and even failure. As a result the active, energetic, and progressive section of the population, which struggles to serve its day and generation in the way that it has always done, instead of leading the rest can move only by the grace and favor of that section of the population which, by its very nature, lacks all the qualities which are needed in order to produce the desired results.

INDIVIDUALISM VERSUS COLLECTIVISM

On a broad view the issue is individualism versus collectivism; the individualist thinks of millions of single human souls, each with a spark of Divine genius, and visualizes that genius applied to the solution of their own problems. His conception is infinitely higher than that of the politician or planner who at best regards these millions as material for social or political experiment or, at worst, as mere cannon fodder.

The individualist believes self-help to be twice blest, for not only does it provide the help required, but it also gives a self-respecting satisfaction in accomplishment, a satisfaction which can never be true of help that is received from others.

When a man is on his own, an individual responsible for himself, his first necessity is to earn a character, a personal character; others must be made by experience of him to learn of his qualities, capabilities, and his defects and limitations. In a planned society he has no need of a character. No national or universal plan can afford to take the least notice of personal character. As an individualist he must also acquire credit; others must be made to know that he is credit-worthy and can be trusted, that what he undertakes he will perform to the limits of his ability. When man is planned, nothing so troublesome is in the least necessary.

The individual responsible for himself must avoid loss, but if he is planned and loss comes out of the bottomless, mythical public purse, he is relieved of that necessity and can waste and lose just as much as his inherent laziness may indicate.

The individual who is responsible for himself must strive to do better, better than his previous performance and better than others; he must apply to the practical things of life the rules learned on the play ground at school. In a planned society, if the urge to move upward has not disappeared altogether, then the only move available to him is into the ranks of the planners where he can arrange the affairs of others and force them down deeper into the passivity of a planned existence. The individual responsible for himself does his best to keep out of the doctor's hands. In a planned society he can indulge in the luxury of invalidism to his heart's content.

Against all this the Socialist professes to believe that the individual can be so trained as to cause his every act to be performed in the interest of society as a whole. His idea is to substitute for the enormous constructive natural power of the self-interest of each of us a manufactured force composed of the theoretical interests of the State. To the individualist this is nonsense—a view much strengthened by the losses and disasters of the last five years in England alone.

Perhaps above all I am an individualist because it makes for honesty. In a society of free men, each acting on his own responsibility, honesty, to put it on the lowest basis, is the best policy. As we move further from the individualistic position into associations, unions, districts, counties, nations, and states, we tend to lose touch with that essentially personal quality. Honesty may be described as a force governing dealings between individuals. When the transactions are between masses, they tend to become less honest; when between nations, there is, indeed, little pretence of honesty about them. That simple circumstance arises not from evil intent, but from the very nature of things.

THE UNDERLYING PHILOSOPHY

All this concerns foundations, a philosophy, a point-of-view from which to start. If only individualism could get these foundations as well laid in the minds of the people as folly has been pumped into them by Socialist's planners, and New Dealers, we could proceed with our social services and other humanitarian plans for the comfort of the less fortunate minority, in the certain knowledge that we were not diverging from the path of progress. As it is, without these foundations, charity, good feeling, desire to help, sympathy, and many other virtues have been brushed aside, and in their place there has been set up the mean, unworthy, degrading, and destructive notion of nonexistent rights for robots.

This article has come to an end without a word about nationalization, profits, wages, or even wars. The real issues are bigger; as I have endeavored to show, they are moral issues. Man has few natural rights and many natural responsibilities, and the happy reader in the cleaner atmosphere of the United States is better able to recognize these greater, all-pervading, considerations. He has only to refer to his own Declaration of Independence for a complete and final judgment on all these matters: "When a long Train of Abuses and Usurpations, pursuing invariably the same Object, evinces a Design to reduce them under absolute Despotism, it is their Right, it is their Duty to throw off such Government."

Engineering the Economic Future

HAROLD E. STASSEN

In this postwar world, there has been an increased questioning in the minds of men concerning the forms of their economic and social systems. Pointing out that a successful economic system must provide incentives for good production and penalties for loafers, Mr. Stassen urges employers to impart factual lessons in economic and social fundamentals to the workers.

I SALUTE the electrical engineers of America. I salute them for their very major part in the contribution which scientists and engineers have made to the lightening of burdens and the brightening of the way of mankind, and to the victory achieved by our forces in the recent war.

There were a number of reasons why I was pleased to be able to address the AIEE at its Winter General Meeting. Among these, three were outstanding. First of all, as a farmer boy, for some few years I had plans for becoming an electrical engineer. While I do not minimize one bit the difficulties and problems of being an electrical engineer, I will frankly confess that there have been quite a few times since that boyhood when I wished I had chosen the career of electrical engineer. Secondly, the founder of the University of Pennsylvania, Benjamin Franklin, had just a little something to do with electrical engineering. Thirdly, I was pleased to accept because doing so would give me an opportunity of expressing a word of appreciation, and doing honor, to Dr. Vannevar Bush,[*] whom I consider to be not only one of the greatest scientists and engineers in the United States, but also one of our outstanding philosophers and thinkers. His recent address to the students at the Massachusetts Institute of Technology stands out as one of the most searching and thoughtful expressions to young America that I have ever seen.

In this address, I shall not endeavor to discuss the field of electrical engineering beyond my brief words of salute and commendation; and I will not engage in any remarks of a partisan political nature. Rather, I should like to make a few observations on aspects of the world's economic and social situation that affect us all, regardless of our occupations and regardless of what our political party may be.

Clearly, in the wake of World War II, there has come a greater questioning in the minds of men around the world concerning the forms of their economic and social systems than at any other time in the history of the world. Men are asking themselves: How shall we manage and organize industry and science and engineering? How shall we distribute commodities? How shall we best advance our own standard of living and that of our fellow men? How shall we join with other nations in solving these great, worldwide economic problems of production, trade, and currency? What can we learn from these other nations—from their experiments, their trials, their thinking? There is a seething, and at the same time a confusion, about this matter of the forms of economic systems and of social systems.

I am not going to attempt to give the answers to those questions. Far be it from me to attempt that. In fact, in even beginning to discuss the central question that is so much before mankind in its effort to make progress and to have peace and liberty, I am reminded of the story told of the college athlete who was looking for an easy course in which he might get a good grade. According to the legend of this particular institution, the young man was told that the course entitled "Religious History" was a cinch for an easy grade and high mark because the professor always asked just one question at the end of the course: "Name the major and minor prophets of the Bible." The student loafed through the course, engaged in many athletic victories, and at the end of the course prepared to answer that one question. To his surprise, when he reached the examination room, the professor had changed the question and there, on the board, was the question: "Criticize the acts of Moses." Well, he was very much perplexed and puzzled. After some delay he wrote this upon his examination paper: "Far be it from me to criticize the acts of Moses. But," he continued, "if you care to know the names of the major and minor prophets of the Bible, here they are."

Thus, I'm inclined to say, far be it from me to attempt to give the answers to these critical world questions of economic and social systems, but if you care to have a few provocative and frank observations on some of the questions they raise, here they are.

BRITISH ECONOMIC SITUATION

I WAS in England on the Sunday night when Sir Stafford Cripps announced the devaluation of the British pound. I was seated with a group of Britishers. It was grim news for them. They realized what would be the impact of the government's extreme devaluation. They knew what it would mean, for they quickly projected their thoughts far beyond the limits of Sir Stafford's message, and were thinking ahead of its repercussions around the world. They were also thinking, naturally, of what the extreme devaluation would do to the British economy itself. It was clear that they were deeply apprehensive about the British economic situation. I will speak of that in some greater detail, and also make some comments on Russia—not with any inten-

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Full text of an address presented at a general session held during the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950.

Harold E. Stassen is President, University of Pennsylvania, Philadelphia, Pa.

[*] **The general session was also the occasion for the conferring of AIEE Honorary Membership upon Dr. Vannevar Bush.**

tion of being critical, but rather to seek to draw some lessons in a tentative way, subject to re-examination and subject to your thought and your disagreement. Clearly, as we look upon the difficulties that confront the British, especially in the very limited standard of living to which they must adhere—notwithstanding the valiant and sincere efforts of their leaders and of this nation toward assisting them and making full allowance for the damage and tragedy of war and the shifting world situation—some very striking things come home to us.

Coal is one of the significant examples. In Britain we know they had a bad example of capitalism in coal, and had it for a long time. Out of that bad capitalism in coal, and all of the evils that arose from it, came nationalization and government operation of coal. Yet, with an all-out government effort now behind the mining of coal, in 1949 they fell 20,000,000 tons below the 40-year prewar average of the bad capitalism in coal. That 20,000,000 tons represents the margin that would provide some chance to play a part in world trade and to raise the standard of living by an over-all increase in production.

We all know of textiles and their importance to the British economy. We know that, in an effort to rebuild the textile industry and get the workers back, the government went all out to pool the cotton. It made special deals through government cotton pools, it allocated production, and it insisted that the goods should not be sold in any great amount in home markets, but should be put into export trade. To step up production, special emphasis was put on recruiting workers to go back to the mills. Yet, in 1949, the production of textiles was around 82 per cent of the prewar production.

Not all spots are that dark. There are some amazing accomplishments in England with which you may be more familiar, in some branches of engineering, for instance. Also, of course, the shipbuilding index is now high, but this is because, in the 1937–38 period on which the present index of 200 is based, there was practically no demand for ships. Therefore, a 200 index for shipbuilding means very little.

As you look at the over-all British production situation, knowing that a larger labor force is now producing, clearly the results are lower per man-hour than before the war. What does it mean? Let me interject that I will bet on the British people, and on the British nation, in the long pull. I will bet that ten years from now we will see them up again, playing a leading role in trade and commerce as well as in government and world affairs. They are going through a very difficult period. We may see a number of elections, even a coalition government, change the course of their economic policies. But I believe that there is a lesson we can draw from the British situation and from our observations of other situations around the world. This lesson, which I present for your reflection and thought, is just this: You cannot develop an economic system unless you take due account of the fundamentals of human nature and the basic philosophy of our way of life.

MAN NEEDS AN INCENTIVE

What do I mean by that? I mean that, taken as a whole, man requires some incentives, or some rewards, for his productive effort, for his successful accomplishment. And, taken as a whole, man requires some penalties and some loss for his failures and for his laziness and loafing. That is the nature of the human being—though not of every individual, nor of any two in precisely the same degree. When you begin to think of a nation or a people, that is, of their basic characteristic, you find that they work best when there are rewards and penalties. That is a fact you ignore at your peril when you attempt to set up national policies of a social or economic nature. That is a lesson that can be drawn from all history and not just from this postwar record of England or from observations of economic systems around the world since the war. Look with me at the studies of civilization by Arnold Toynbee, that great historical scholar and thinker. As he analyzes the rise and fall of nations since earliest time, you find that civilizations grow and prosper and produce when these rewards and penalties are present. There comes some challenge to a civilization when there is a penalty if it fails. If the civilization is to survive and prosper, it must offer some rewards to its members who are looked upon for production; it must possess some creative ability in its leadership and among its people; it must exercise its authority and leadership by conferring such rewards. Not otherwise can it prosper. Conversely, you find in those studies of civilizations through the thousands of years that, when there is a situation that encourages a blissful lassitude, or when there is practically no challenge before a people, or when those with creative brain power ignore their responsibilities, the tendency is to deteriorate, to decay. Likewise, if there is some crushing obstacle that cannot possibly be overcome, then, too, the tendency is for a civilization to decay or be destroyed.

You cannot go through Toynbee's studies of civilizations, which I think are the most thought-provoking, careful historical studies of the whole sweep of centuries, without those conclusions coming to you and being corroborated by your other studies of history. When you pause to think, does not all of this check with what you personally know of human nature? If an individual has no kind of challenge, no kind of reward or incentive before him, no penalty for failure, the tendency on the average will be for him to make little or no constructive contribution to society. On the other hand, if there are crushing burdens, they may break him.

I grant that, in two individuals, measurement of the standards are not fixed and definite. Human nature is variable, but these fundamentals are there nevertheless.

KNOW THE ECONOMIC FACTS

What does this all mean in terms of the future economic and social systems of the world? What does it mean to the people of the United States, who, though they comprise only 1/16th of the world's population, produce almost one-third of all the world's goods and services? Can Americans learn the lesson from world experience without personally having that tragic bitter experience? If they are to avoid the sad results of ignoring the fundamentals of human nature as they affect economic systems, Americans must be made acquainted with the economic facts of the world today. If they have those facts, I believe that they will reach sound conclusions.

Let me state it this way: I am inclined to believe that the men and women in both political parties in America; the workers, the farmers, the white-collar people, the engineers, lawyers, doctors, professors, and all, will, if the facts are dramatized, come through to this clear understanding: Any time you say to your people that they cannot keep at least one-half of the results of their work, whether of their hands or their brains or their capital, you are undermining the vigor, strength, and productivity of your economic system in the long pull. Conversely, any time you say to your people that they can do more than half as well—almost 75 per cent as well—by loafing with their hands or their brains or their capital, likewise you are undermining the vigor and productivity and strength of your economic system. In other words, the producer must have a reward, the loafer must have a penalty.

Let me apply this principle, just for a minute, to the situation in postwar England, again emphasizing that I do it, not for the purpose of criticizing the British, but to draw a lesson for America from their experience. I spoke of the low production in the British textile industry. While in England I talked with workers from the mills. I knew that, after the war, their orders had piled up six to eight months ahead, but at the same time many looms were idle. I said, "Why don't you work overtime?" They said, "Why should we work overtime? We work 20 shillings worth, but the standard rate of taxes on taxable income lets us take home only 11 shillings of it. When we work overtime, we get into a higher tax bracket. Then, if we want to buy something that the government says isn't a necessity, we find a 100 per cent purchase tax. The result is we get $5^1/_2$ shillings of goods for 20 shillings of overtime work. So why work overtime?"

Then I asked them about absenteeism. They said, "Yes, it is rather hard to keep down absenteeism. If you take off your taxes and your transportation costs, and if you have quite a few children, for whom you get the family allowance even if you don't work, you can frequently do just about as well by working only a few days a week instead of full time."

With all these benefits, even though they were granted with the best intentions, the workers begin to realize that they can do more than half as well by not being good producers as they can by doing their all-out best. You can see that this has happened in England from the production figures. You can hear it from the lips of workers.

PENALTIES AS INCENTIVES

If that analysis is true, how are we to account for increases in production in Russia? From studies made over a period of years and from personal observation in the Moscow area, the Urals, Kiev, the Ukraine, Stalingrad, and Leningrad—in factories of different kinds—I know that the worker is given very few incentives. There has been an attempt to put in the speed-up and piece work and to increase the ruble reward, but the rubles will not buy much. However, the penalties have been increased. In Russia the penalty for not producing is not merely that you eat less or that you get fired. The penalty can be death. Frequently it is banishment or exile—a trip to Siberia, which may amount to a death penalty—or local punishment.

This is not just a tale out of a story book. You soon learn that if you ask where someone is, if they know, they will tell you. But if he has been taken away and has not been heard of again, you get a slight shrug of the shoulders and a change of subject. If, in talking about 5-year plans and quotas, you talk to a director of a collective farm and ask how long he has been there, he is very likely to say just a few months or a very brief time. If you ask where his predecessor is, you usually get a shrug of the shoulders and a change of subject. Then if you ask whether this collective farm reached the 5-year plan last year, he will say no. Of course, the two things fit together very directly and as you observe the same striking coincidence on farm after farm, and in industry after industry, you realize the nature and extent of the penalties that the Russians have substituted for incentives in their slave state.

If you want to go to the extreme of obliterating human liberties and of inflicting ruthless penalties, then you can reduce the incentives and get a certain limited production—more perhaps than under some other systems. But that production will be only a fraction of what you get under a system of individual initiative and incentive and freedom. Of course, in speaking of these fundamentals, I am seeking to get down to a sound basis on which we of both parties in America, forgetting partisanship, which will flare up at periodic intervals, can think through to solutions of the problems that confront us. Benjamin Franklin said, "They that can give up essential liberty to obtain a little temporary safety deserve neither liberty nor safety." There is much wisdom in those words which might be needed by the men and women of both political parties today.

FACTUAL ECONOMIC LESSONS

What I am saying herein to the members of the engineering profession, I say very hopefully because I know full well that, just as you have made tremendous contributions to the advance of industry, you are thinking in an increased degree about the whole wide range of economic problems and of the systems that are being proposed to meet those problems. I believe that you will think through the problems involved in the whole complex relationship between sound currency and incentives and of the danger of imposing crushing taxes which are intended to provide security but which may actually destroy security. These fundamental lessons can be brought across to the American workers only by the companies for whom they work. This is my major proposal for implementation.

I do not believe that full-page advertisements or pamphlets of the National Association of Manufacturers or of any Chamber of Commerce, or even of an engineering society, can get the message across to the workers of the United States. Take a poll down almost any street in America and you will find that, as a whole, the people have no opinion or a very low opinion of business associations and combinations. They have a tendency to think of such associations in the abstract, as combinations that have objectives opposed to their own objectives. However, if you ask them their opinion of almost any of the great companies of this country, you will get, on the whole, a favorable reaction, because the people you ask know the company for the products which it makes and which they use, and they see how those products have improved their standards of living. They know the company as a source of wages for themselves or for their friends or relatives. They know it, and this is true of virtually all the companies notwithstanding some of the attacks, for the contribution it has made to the total economic and social development of this country. That is why I say that the simple factual lessons in economic and social fundamentals must come to the workers of America from those same companies and from the executives and engineers and leaders of those companies. These lessons must be presented to them without propagandist coloring and exaggeration and without partisanship, and they must repeat simple fundamental facts.

Here is an example of the kind of facts I have in mind: According to the best information that I have, a worker in an electrical manufacturing company in America can buy shoes for his children, clothing for his family, a shelter over his head, for about one-third fewer hours of work in his electrical manufacturing company than can the worker in an electrical manufacturing company in any other nation in the world. That worker's higher real wages are made possible not only by technical advances, but by the over-all operation of a free economy and of a modern capitalistic system.

Facts of that kind could be worked out in great detail for a vast number of individual industries by staffs of the Association of Manufacturers. The data that would be compiled would include such related facts as the effects of savings and sound currency on the real standard of living and the true security that is based on high production. In addition to such facts, we must bring to the men and women of this country in all walks of life the message that the richness of their economic life is inseparably intertwined with the great philosophic principle that man was meant to be free, the principle that motivated our founding fathers.

Doing that we will learn the lesson but avoid the bitter experience that lies in the failures of other economic systems.

We must fully recognize and accept and take hold of the principle on which this nation was founded if we are to contribute to the future liberty of the world and are to raise the standard of living of peoples everywhere. By means of that principle we can pierce the iron curtains, and can get through totalitarian barriers to the men and women of the world, for it is a vital principle that offers brighter prospects of future peace and rising standards of living for all than does any principle that ignores man's freedom and denies his dignity as a human being.

Analogue Computers to Be Used in Hydroelectric Studies

Electronic computers to give a television-like picture of how water behaves may help make possible more efficient use of water supplies and water power, according to engineers at the Massachusetts Institute of Technology. Under a special grant from the Research Corporation of New York, the hydraulics division of the MIT civil engineering department is studying possible applications of so-called analogue computers to make hydraulic engineering predictions faster and more accurately.

Using these computers, it is expected to demonstrate immediate solutions to several flow problems—the rise in a river below a reservoir when a flood crest enters the reservoir from above, for instance. To calculate this flooding effect requires consideration of the size and shape of the reservoir and its outlet, as well as the amount of water coming in.

The calculation is performed by an array of interconnected electronic computers. Connected together in various ways, the computers can be made to give the answers to a great variety of specific mathematical problems. The results are viewed on a screen similar to that of a television receiver.

Typical water behavior problems of practical importance occur in every-day operations of hydroelectric plants. When the gate on a 5-foot pipe to a turbine is opened, the effects throughout the water system and the plant's electric network may be widespread, important, and difficult to predict.

There is complication, too, in keeping the water pressure to a hydroelectric generating unit constant as the power load or generator speed changes. Such speed changes have subtle effects through the entire water system of the hydroelectric plant, and many of these effects are not clearly understood. Some are so complicated to calculate that power plant engineers have never studied them; in practice, systems are empirically made to perform adequately without a clear understanding of why they do so.

Now there is the possibility of using analogue computers to obtain a scientific and relatively inexpensive solution to such problems. The result may be better performance at less cost in future hydroelectric installations.

The first problem up for detailed study is the behavior of surge tanks. It is planned to make a thorough analysis of such tanks—in the hope of finding a way to determine the sizes and designs most suited to particular needs.

In a longer view, it is believed analogue computers may be a meeting ground for electrical and hydraulic engineers working on hydroelectric generating problems. Hydraulic engineers have generally made their hydroelectric plant studies on the assumption that the electric load on the plant remains unchanged. Likewise, electrical engineers have assumed that the hydraulic part of the problem is a basic constant. In actual practice, the two are variable and interrelated; changes in the electric load affect the hydraulic system, and, in turn, changes in the hydraulic system affect the electric power output. It is hoped that the use of these computers soon will go beyond the simple calculations now economically feasible.

Novel Test Circuits for Protective Relays

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IN THE TEST, calibration, checking, and setting of protective relays, and in the determination of their characteristic operating curves, it is of course necessary to apply to the relays the quantity or quantities which are expected to operate it. Problems are sometimes encountered in obtaining suitable test facilities, particularly when two or more variable a-c quantities are involved, and the phase angle between the quantities must be known or controlled. The solution to such problems generally may be obtained in the laboratory by special circuits and equipment.

The variable-ratio autotransformer as a very convenient device for varying a voltage has received considerable attention, and, accordingly, it has enjoyed widespread acceptance. One of its capabilities, however, seems to have been quite generally overlooked. This is its possibilities as a variable-ratio current transformer (see Figure 1). The use of the device for this latter function makes it very convenient in the test of certain differential relays.

Referring in particular to percentage differential relays, two currents are required, and one must be adjusted with respect to the other until relay operation results. It is convenient in some cases to establish only the reference current by means of a load circuit, and, by passing this current through a portion of the variable-ratio autotransformer, obtain a controllable fraction of it for reuse in the relay circuit. By this means, two in-phase currents, both controllable, are obtained with only one load as shown in Figure 2.

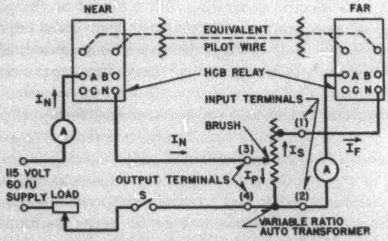

Figure 1. Connections illustrating the use of the variable-ratio autotransformer in step-down ratio

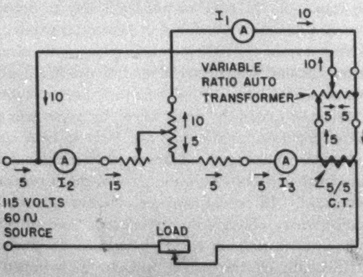

Figure 2. Circuit illustrating the use of the variable-ratio autotransformer in step-up ratio

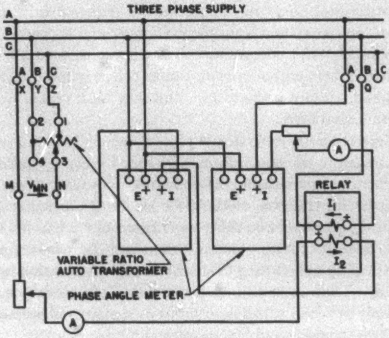

Figure 3. Circuit for determining the phase angle characteristic of a relay operating on two currents

In using the variable-ratio autotransformer in this fashion, its adequacy from the standpoint of voltage and current rating should be determined. If the voltage requirements of the relay at the desired currents do not exceed 115 volts, then a device rated at 115 volts can be used in step-down current ratio without its drawing an excessive magnetizing current and thereby disturbing the in-phase relationships and the wave form. Regarding current requirements, it has been found to be feasible to operate the device at momentary overloads considerably in excess of the continuous-duty rating for the short length of time required to obtain an observation on relay operation.

A source of current of readily adjustable phase angle may be obtained by connecting the variable-ratio autotransformer between two terminals of a 3-phase source, and drawing the test current from the remaining terminal and the slider of the autotransformer (see Figure 3).

Relays operating on sequence components require special circuits or connections for test. In the laboratory, the necessary distortions, representing fault conditions, may be produced by suitable connections to the test source. In the field, operating the usual test switches in a prescribed fashion and making temporary connections at the relay or filter makes it possible to derive suitable sequence quantities from the load current and voltage.

Digest of paper **49-262**, "Novel Test Circuits for Protective Relays," recommended by the AIEE Committee on Relays and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Transient Characteristics of D-C Motors and Generators

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Before World War II most Navy vessels with d-c systems used excessively large safety factors in overload devices because accurate knowledge of the exact performance of d-c rotating machinery was not available. In order to eliminate rule-of-thumb calculations in the design of new protective equipment, a study of transient phenomena in the d-c system has been made.

SINCE THE FIRST installation of electric power on board the *USS Trenton* in 1883, the United States Navy has always been a major user of d-c power. After the introduction of 440-volt alternating current into the Navy with installations on the Farragut-class destroyers in 1932 there was still a continued use of a sizable amount of direct current. All vessels having a-c systems required some direct current for powering excitation supplies, searchlights, battery chargers, and interior communications. Although alternating current had become the accepted standard, smaller vessels, such as landing craft and patrol craft, retained d-c systems in the interest of simplicity. Other vessels, such as large tenders, repair ships, tugs, and submarines, had relatively large d-c power plants installed for electric propulsion purposes.

Thus the Navy, having extensively used direct current for ship's service and propulsion power plants for over a long period of years, has always been vitally interested in the question of transient performance of d-c rotating machinery and the effect of the transients on system operation. Of special interest has been that phase of system study work which deals with fault current analysis and the application of protective devices to the power plant. In the early days of small capacity plants, fault current analysis was not of major importance since the available amount of short-circuit current in the system was relatively small and most of the protective devices, which had been primarily designed for shore station use, had more than adequate interrupting capacity to meet the application requirements. Thus accurate knowledge of fault currents that could be obtained was inconsequential. As the electric loads on Naval vessels started to increase at a great rate shortly before World War II, with the resultant increase in generating capacity and available fault currents, system study work received a new emphasis. Unfortunately, the mathematical tools available to the a-c system designer, which gives him the ability to calculate such items as subtransient reactances from the geometry of the machines, are not readily available to the d-c system designer. The engineers concerned with d-c system work had to satisfy themselves with rule-of-thumb methods for calculating available short-circuit currents in the system and used excessively large safety factors in their protective devices to offset the probable inaccuracy in their system study work. In most cases, however, this worked out entirely satisfactorily because of the fact that high-interrupting capacity protective equipment was being applied to low-capacity power systems. Where test data could be obtained on the machinery to be used, a more thorough and accurate system study design could be made. Generally speaking, however, very little test data were available to the system designer.

In connection with the design of a Naval vessel having a large d-c propulsion system, the Navy initiated the development of completely newly designed rotating machinery. Machines of new voltage ranges, speeds, and ratings were designed. Associated with this machinery development program was the design of new fuses, circuit breakers, and contactors. Thus the application engineer was faced with the problem of setting up design and performance specifications for this new protective equipment without accurate knowledge of the conditions under which the equipment might have to operate. In the case of shipboard d-c systems where freedom from commutator flashover and reliable circuit breaker operation are extremely important, consideration of the performance of d-c machinery under fault conditions is extremely significant. This is especially true in the larger capacity systems where excessive fault currents cause commutator flashover and extremely low-fault currents make the attainment of circuit breaker selectivity extremely difficult. In order to set up successfully design specifications for protective devices that will operate reliably with the rotating

Figure 1A. Schematic diagram of the d-c machine being studied

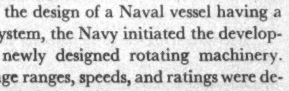
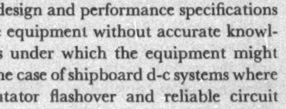


Figure 1B. Equivalent representation of d-c machine

Effective internal resistance represents all factors restricting flow of current from generator



Essentially full text of paper **49-229,** "Transient Characteristics of D-C Motors and Generators," recommended by the AIEE Committee of Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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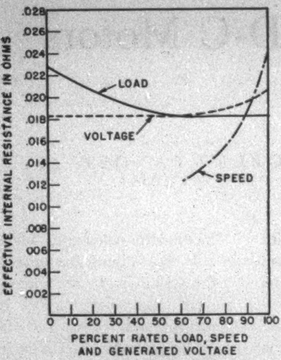

Figure 2. Effect of initial operating conditions on effective internal resistance of a 1,100-kw 415-volt 750-rpm generator

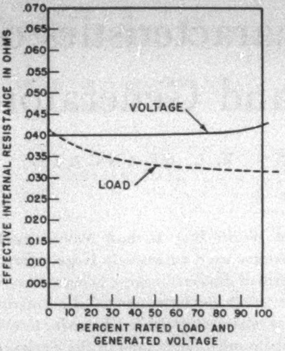

Figure 3. Effect of initial operating conditions on effective internal resistance of a 300-kw 345-volt 1,200-rpm generator

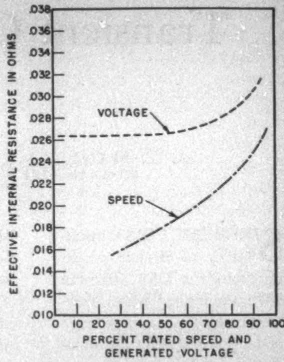

Figure 4. Effect of initial operating conditions on effective internal resistance of a 1,375-horsepower 415-volt 280-rpm motor

machinery, it is important that the application engineer have the following information:

1. The maximum short-circuit current of motors and generators in the system.
2. The rate of rise and decrement of the short-circuit current of the motors and generators.
3. Information relative to the flashover characteristics of the rotating machinery.
4. Information relative to the effect of changes in voltage, speed, and machine loading on the short-circuit characteristics of the machinery.

In attempting to set up design specifications for this particular power plant which would result in the smallest possible size of protective equipment, an investigation was made into the various methods of calculating the transient performance of d-c machinery. Some theoretical treatises on this subject were available; however, most of these were conflicting in theory and results, and generally all were too unwieldy to be of use to the application engineer. In this instance where the machine design work was paralleling the protective device development, the system engineer was hampered by the fact that there was not a thoroughly reliable mathematical tool available with which he could calculate the transient performance of the rotating equipment. It was immediately apparent that if the Navy was to continue using d-c systems, and in some cases this could not be avoided, some means must be established for the accurate calculation of the transient performance of d-c machinery from the geometry of the machines concerned.

After a complete review of the various technical papers on this subject and many discussions with manufacturers of Navy d-c rotating machinery, three technical papers[1-3] were investigated for application to shipboard system analysis. Using certain methods prescribed in these papers for the d-c calculations, various sizes of this newly designed rotating machinery were calculated to determine the peak short-circuit current. In all cases, the results obtained appeared excessive.

Since these machines had not as yet been built, there were no means available for checking these calculations. Accordingly, it was deemed necessary at that time that the theoretical considerations set forth in the foregoing papers should be checked with test data on Navy-type equipment. In order that enough test data could be obtained to evaluate completely the theoretical considerations, a mock ship's system was set up, complete with propulsion motors, propulsion generators, and auxiliary motors in various horsepower ranges. Instrumentation was installed in this system for a twofold purpose:

1. To measure the peak short-circuit current and rate of rise and decrement of short-circuit current under various conditions of loading, speed, voltage, and external fault resistance.
2. Instrumentation to determine the internal phenomena under fault conditions. This involved measuring the change in flux in various portions of the machine.

It was anticipated that the first phase of this test program would result in data which could easily be checked against values obtained by calculation. The second phase of the program regarding the internal phenomena of the machines is a longer range program, the results of which are expected to simplify present theory or evolve new theory.

The purpose of the following discussion is to demonstrate the scope of these tests and their relationship to the theoretical considerations of the problem. The data described herein merely cover the highlights of the test work performed and are presented to the extent that they assist in an understanding of the factors involved in the transient characteristics of d-c machines.

EQUIVALENT CIRCUIT

The selection of a suitable equivalent circuit for adequate representation of the d-c machine presented schematically in Figure 1*A* will depend upon the application of the circuit in later studies. One form of simplified representation is found in Figure 1*B*. The effective internal resistance represents all factors tending to restrict the flow of current from the generator. These factors are armature circuit ohmic resistance, brush contact drop, reactance voltage, and flux reduction and distortion. The voltage E_g represents the generated voltage prior to short circuit which is assumed to remain constant during the short circuit whereas the flux reduction and distortion are treated as ohmic resistance.[1]

It should be noted that this circuit is applicable only for the computation of peak values of short-circuit current for individual machines or for the total value of several in a system. Reasonable accuracy can be expected in a system calculation if the time to reach peak current is essentially equal for all machines on the system and if the effective internal resistance is accurately known. Where the transient of the current is desired, a more nearly complete representation of the machines with an equivalent circuit will be required. Such a circuit would require resistance and inductances to represent the armature and field circuits. However, the required accuracy of calculations would have to justify such elaborate computations as this implies.

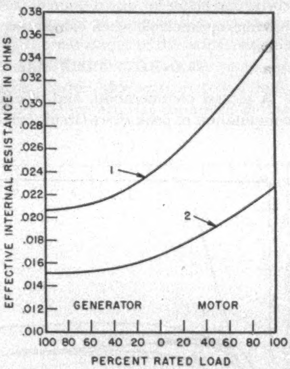

Figure 5. Effect of change from motor to generator action as initial condition on effective internal resistance

1. 1,375-horsepower 415-volt 1,300-rpm motor

2. 1,375-horsepower 415-volt 280-rpm motor

EFFECTIVE INTERNAL RESISTANCE VARIATION

The experimentally obtained transient resistances are plotted in Figures 2 through 4 against the parameters of load, speed, and voltage. Referring to Figures 2 and 3, it is noted that the magnitude of load prior to short circuit has a sizable influence on the resulting peak short-circuit currents or effective internal resistance, and that the peak current increases and resistance decreases with increasing load. The reason for this behavior is not evident, although it is suspected that higher resistance in the field circuit at lower loads may result in a faster deterioration of flux linkages which may augment the reduction in air gap flux beyond that anticipated from the increase of leakage flux during transient loading. A comparison of the percentage decrease in internal resistance between a lightly differentially compounded machine of Figure 2 and a more heavily differentially compounded machine of Figure 3 tends to verify the inference, namely the percentage increase in field circuit resistance, between full load and no load, and in the transient field current due to transformer action of the armature circuit during a short circuit. Thus the change in the rate of destruction of flux linkages for a change of load from full load is percentagewise higher in the heavily differentially compounded machine. By this token, it is expected that the magnitude of short-circuit currents from a cumulatively compounded machine would not be unduly influenced by the initial load.

The speed also influences the machine effective resistance. The speed characteristics were obtained for the two large machines and are graphed on Figures 2 and 4. The effect of speed change is consistent for all units, that is, the internal resistance rises and the peak current correspondingly decreases with increasing speed. This trend is expected, for the speed proportionally affects the reactance voltage which, appearing as an equivalent brush drop, adds to the magnitude of machine effective resistance.

If the machine effective resistance were constant, then the peak current would increase with the generated voltage. However, it is observed in Figures 2, 3, and 4 that this resistance is constant up to 50 per cent voltage but above this voltage the machine resistance rises. It is inferred that this effect is due to an increase in leakage flux owing to increased saturation of the pole iron. In addition, there is an accompanying increase in reactance voltage since the crowding of the flux in the pole tips increases the steepness of the flux distribution curve at the neutral point and results in a decrease in commutation time. The behavior of a machine, relative to short-circuit contribution, when operating as a motor or as a generator, is of practical interest. Two motors were operated, each as generator and as motor, at similar load, voltage, and speed conditions. Referring to Figure 5, it is noted that the peak short-circuit current is less for motor action than for generator action; and that this difference in current decreases as the initial load is decreased.

PEAK SHORT-CIRCUIT CURRENT

In an attempt to verify the validity of existing theory relating to short-circuit characteristics of d-c machines,

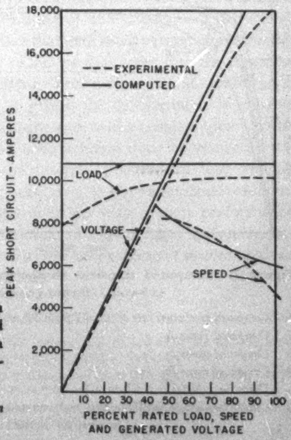

Figure 6. Comparison of computed and experimental data on peak short-circuit current

1,100-kw 415-volt 750-rpm generator

calculations of peak short-circuit currents were made for the fault conditions to which these machines were subjected.

These improvements may result only from the acquisition of a more fundamental knowledge of the machine's internal transient phenomena. Hence this work is being continued along the theoretical approach with this objective in mind. The factors of internal and external ohmic resistance, decay in air gap flux, and the development of a reactance voltage opposing the generated electromotive force are considered to be all the variables that enter into the calculation of short-circuit currents. However, weighting these effects in the proportions occurring in a d-c machine may not be accurately expressed by the existing relations.

This observation is illustrated by a set of experimental characteristics on the 1,100-kw generator which are plotted in Figure 6 and compared with a corresponding set of computed characteristics. These curves attempt to demonstrate graphically the relation of peak short-circuit currents developed with variations of operating conditions of load, speed, and generated voltage.

Focusing the attention on the curves showing the effect of load, it is observed that the peak short-circuit current is a function of preshort-circuit current while the calculated values are entirely independent of initial load. There is no factor in the equations which recognizes the effect of load, yet a change in load from zero to 50 per cent raises the peak current by approximately 20 per cent, a factor that cannot be neglected even in an approximation.

Referring to the effect of voltage, it will be recalled that the effective resistance of a machine is independent of generated voltage for voltages below 50 per cent, and rises appreciably beyond it. The equations involve the voltage only in the flux reduction factors, r_z', for uncompensated or partially compensated machines. Although the increase in the effective resistance of this machine, from half to full voltage, is 30 per cent, the calculated rise in value for r_z' over the same region is only 10 per cent. As r_z' is one of the three factors embraced by the effective internal resistance, r_d', while the other two are independent of voltage, it is evident that the effective resistance is inadequately influenced by the change in the calculated r_z' with voltage.

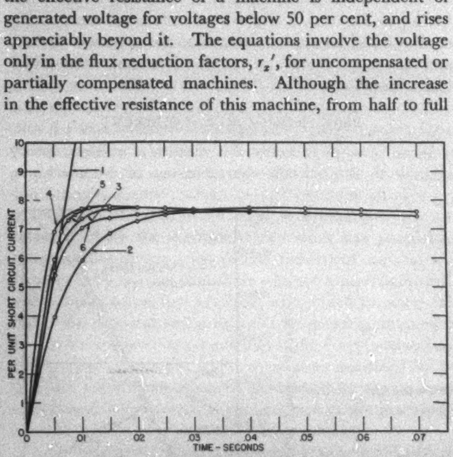

Figure 7. Computed transient short-circuit current, 1,100-kw 415-volt 750-rpm generator

1. *Computed maximum rate of rise* $=2.95\times10^6$ *amperes per second*
2. *Computed curve for* σ_a
3. *Computed curve for* $2\sigma_a$
4. *Computed curve for* $3\sigma_a$
5. *Curve* $3\sigma_a$ *shifted to 0.67 curve 1*
6. *Curve for actual oscillographic test, maximum rate of rise* $=4.18\times10^6$ *amperes per second*

In comparing the experimental to the calculated curves showing the effect of speed, it is observed that the calculated values describe a nearly straight line relation; the experimental values, although following the same trends, indicate a sharper decrease in peak current with speed, at the larger magnitudes of speed. The calculated effect of speed is apparently insufficiently descriptive of the physical behavior of the machine. The speed enters in the calculations of the reactance voltage factor, r_b', and the flux reduction factor r_z', as a linear function, except at very low speeds where the correction factor for distribution of current in the brush face becomes appreciable when calculating r_b'.

TRANSIENT ARMATURE CURRENT

A second consideration, and of equal importance with computation of peak short-circuit current, is the prediction of rate of rise and decrement of the transient current. The accuracy with which the rate of rise can be predicted has been demonstrated by test and calculation to be as accurate as the computation of armature inductance for conditions prior to the short circuit. Curves number *1* and *6* of Figures 7 and 8 and curves *1* and *5* of Figures 9 and 10 indicate the agreement between computed and experimental data. Calculation of the complete transient build-up is difficult to achieve due to the effect of saturation in generated voltage during the current rise. It has been proposed

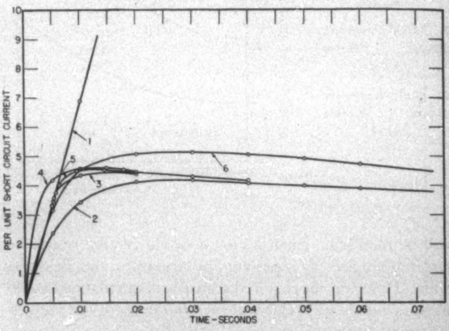

Figure 8. Computed transient short-circuit current, 300-kw 345-volt 1,200-rpm generator

1. *Computed maximum rate of rise* $=0.792\times10^6$ *amperes per second*
2. *Computed curve for* σ_a
3. *Computed curve for* $2\sigma_a$
4. *Computed curve for* $3\sigma_a$
5. *Curve* $3\sigma_a$ *shifted to 0.67 curve (1)*
6. *Curve for actual oscillographic test, maximum rate of rise* $=0.80\times10^6$ *amperes per second*

that the assumption should be made that the time constant of the armature circuit be decreased by two-thirds as the armature current reaches its peak values.[1] Experimental evidence indicates that this represents too great a decrease in inductance. Results presented in Figures 7 and 8 show that for these machines the inductance decreased approximately 50 per cent as indicated by curve *3*, whereas data shown in Figures 9 and 10 indicate that the oscillographic trace can be more nearly duplicated with a curve representing a fixed value of armature inductance. However, such an assumption is basically incorrect since the rate of rise at any point on the curve is influenced by voltage as well as inductance at the corresponding interval. Thus a procedure which recognizes only inductance change is incomplete.

The remaining portion of the transient, that is the decay of current after peak value, is associated with the shunt field circuit and its time constant. Accurate measurement of this time constant is difficult to achieve because of the necessity of duplicating the saturation of the armature and pole faces and distortion of field flux that accompany the high-armature currents under short-circuit conditions. Therefore the shunt field inductance was computed on the basis of complete saturation of the armature teeth. This reduces the inductance to approximately one-tenth the base value at no load. Although the results of the approximations are fairly close to test data, there are additional factors such as mutual inductance and compensation which must be considered. It is important that accurate predictions of the shunt field inductance be possible since it can materially influence the peak value of short-circuit current as evidenced from Figure 10. The computed value of peak current without giving consideration to this decrement is 9.27 per unit, whereas this becomes 7.74 per unit when the decay of the shunt field is considered. Thus it becomes evident that the influence of the shunt field on the peak fault current cannot be ignored.

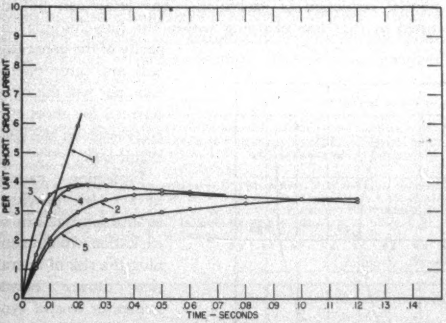

Figure 9. Computed transient short-circuit current, 1,375-horsepower 415-volt 280-rpm motor

1. *Computed maximum rate of rise* $= 0.79 \times 10^6$ *amperes per second*
2. *Computed curve for* σ_a
3. *Computed curve for* $3\sigma_a$
4. *Curve* $3\sigma_a$ *shifted to 0.67 curve (1)*
5. *Curve of actual oscillographic test—two rates of rise noted. First* $= 1.14 \times 10^6$ *amperes per second. Second* $= 0.53 \times 10^6$ *amperes per second*

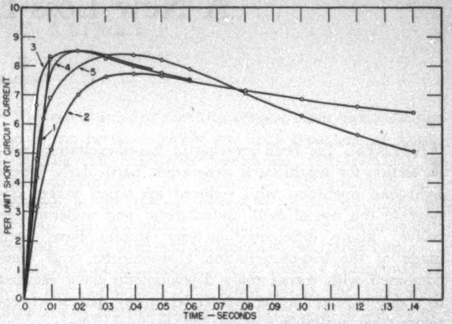

Figure 10. Computed transient short-circuit current, 90-horsepower 250-volt 1,750-rpm motor

1. *Computed maximum rate of rise* $= 0.248 \times 10^6$ *amperes per second*
2. *Computed curve for* σ_a
3. *Computed curve for* $3\sigma_a$
4. *Curve* $3\sigma_a$ *shifted to 0.67 curve* (1)
5. *Curve for actual oscillographic test, maximum rate of rise* $= 0.29 \times 10^6$ *amperes per second*

In view of the difference between experimental and computed values of short-circuit currents using present techniques, it is necessary that the theory of transient characteristics of d-c machines be extended to provide the accuracy necessary for attaining the optimum in shipboard system design. Although the factors contributing to the limitations of short-circuit current, namely armature and external circuit ohmic resistance, brush contact drop, reactance voltage and flux distortion and reduction have all been considered, the application of these in calculating transient response from machine constants appears to be inadequate. The analysis of the transient response must include those factors that will show the variation in initial load and voltage, establish a more nearly complete analysis to illustrate the magnitudes of flux change and distortion, and to recognize the fact that generated voltage is a variable.

The large number of factors that enter into the transient response of a d-c machine under short-circuit conditions is very significant. As a result, the development of suitable relationships for armature and field current appears to be difficult. Additional work is being done to secure an accurate measure of the internal phenomena that are associated with this condition. At the same time results of the study are being correlated with system performance studies to assure completion of a theoretical approach that will be applicable to this over-all problem of system analysis under transient conditions.

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2. **Current and Torque of D-C Machines on Short Circuit, T. M. Linville.** AIEE *Transactions*, volume 65, 1946, pages 956–65.

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A New Loss-Excitation Relay

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INTEREST has been growing in loss-of-excitation protection for synchronous generators, particularly where light-load operation with reduced excitation makes impossible the use of field undercurrent and undervoltage relays. Many differential-analyzer studies have been made of the loss-of-excitation characteristic, and these combined with recent relay developments have resulted in a simple relay having greater selectivity than has heretofore been available.

The new loss-of-excitation relay is of the so-called "mho" family, similar to distance relays used for transmission-line protection. It is a single-phase relay arranged to operate from a phase-to-phase voltage and the difference between the phase currents at the terminals of the generator to be protected. The operating characteristic on the *R–X* diagram is a circle centered on the $-X$ axis and offset completely from the origin, as shown in Figure 1. The diameter of the circle and the offset are independently adjustable.

If the offset is approximately one-half of the direct-axis transient reactance of the generator, and if the diameter is approximately the direct-axis synchronous reactance, the relay will operate for all cases of complete loss or substantial reduction of excitation, and will not operate for any other kind of normal or abnormal system-operating condition. Operation will occur before the first pole is slipped when the excitation is lost completely.

The impedance "seen" by the relay for various conditions, and the area within which this impedance will operate the relay when shown on an *R–X* diagram like Figure 1 clearly demonstrate the relay's selectivity. Loss-of-excitation characteristics start outside of the relay operating area and enter it at varying times after the excitation is affected, but always before the first pole is slipped. These times in seconds are given in Figure 1. Loss-of-synchronism characteristics never enter the operating area except for substantial reduction of excitation. The relay can be adjusted so that line charging within the line-charging capacity of the generator will not cause operation, nor will the relay operate for short circuits even on the generator bus.

Protection cannot always be provided against partial loss of excitation without running the risk of operation during power swings or loss of synchronism. Where such protection is required, the relay should merely operate an alarm rather than trip the generator circuit breaker. Short-circuiting of part of the field poles can cause damaging vibration, and other protective means should be employed.

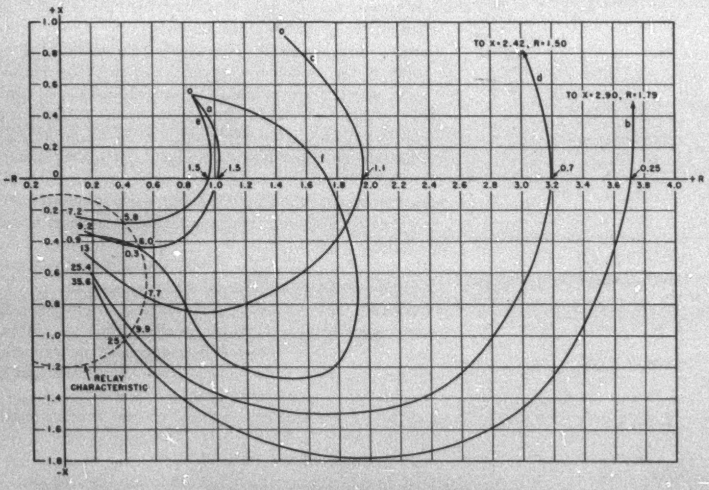

Figure 1. Loss-of-Excitation Characteristics

Curve	*Machine Type*	*Initial Load (Per Cent of Rated)*	*System Impedance (Per Unit)*	*Type of Field Failure*
a	*round rotor*	*100*	*0.015+j0.1*	*short-circuit*
b	*round rotor*	*29.4*	*0.015+j0.1*	*short-circuit*
c	*salient pole*	*58.8*	*0.015+j0.1*	*short-circuit*
d	*salient pole*	*35.3*	*0.015+j0.1*	*short-circuit*
e	*round rotor*	*100*	*0.03 +j0.2*	*short-circuit*
f	*round rotor*	*100*	*0.015+j0.1*	*open circuit*

Digest of paper 59-260, "A New Loss-Excitation Relay for Synchronous Generators," recommended by the AIEE Relay Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

C. R. Mason is with the General Electric Company, Schenectady, N. Y.

Temperature Rise Values for D-C Machines

AIEE COMMITTEE REPORT

THE RESULTS of heat run tests made jointly by the Allis-Chalmers Manufacturing Company, Century Electric Company, General Electric Company, Reliance Electric and Engineering Company, and Westinghouse Electric Corporation on a motor exchange program involving motors at 1750 rpm, 40 degrees centigrade open, from 1/2 to 50 horsepower, were reported in a previous article.[1] It was recommended that Table I of the American Standards Association *C-50 Standard*[2] be expanded, using values derived from the results of tests, to cover short-time rated motors and to include limiting values of temperature rise by the resistance method corresponding to existing values for the thermometer method for all windings.

In publishing the previous article the committee recognized the need for similar data on a sufficient number and variety of machines to make the results representative of d-c machines generally. An exchange motor test program on large machines was not practical, but the same companies offered from their engineering data files test results on a large number of machines of all sizes. Results have been published in a second article[3] with modifications of the previous recommendations. The proposed changes are shown in Table I.

It is recommended that this revised table supersede the one of the previous article and that expansion of Table I, of American Standards Association, *C-50 Standard* be made accordingly. For reasons of both simplicity and economy in the testing procedure of d-c machines, in general, the committee recommends the thermometer method as the preferred or standard test procedure.

Test data on 116 machines from about 4 horsepower to 7,000 horsepower and from about 100 to 1200 rpm were furnished by the five companies. The ratio of rise by resistance to rise by thermometer for these is 1.43 for armature windings and 1.18 for shunt field windings.

For six of the machines tested there were duplicate units totalling 420 machines altogether. A statistical analysis was made of the test data from these showing the number of machines out of any total number of machines tested which can be expected to vary from the true result by any given percentage error. This shows that the resistance method is as accurate for low resistance armature windings as for shunt field windings and that error can be either above or below the true temperature while with the thermometer method error is below in every case.

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2. Rotating Electrical Machinery. *C-50 Standard*, American Standards Association (New York, N. Y.) 1943.
3. Temperature Rise Values for D-C Machines—Part II, **AIEE Committee Report.** AIEE *Transactions*, volume 68, 1949.

Table I. Proposed New Table

The Temperature Rises in Degrees Centigrade Apply to the Several Classes of Machines as Given at the Heads of the Respective Columns		Method of Temperature Determination	General Purpose Generators and Motors		Totally Enclosed, Totally Enclosed Fan-Cooled, Explosion-proof, Waterproof Dust-tight, and Submersible Motors Continuous Rated		Motor and Generators Rated 30 Minutes to 2 Hours Inclusive		Motors and Generators Rated 15 Minutes or Less		Generators Having a 2-Hour 25 Per Cent Overload Rating at Continuous Load		Generators Having a 2-Hour 25 Per Cent Overload Rating and Generators Having a Nominal Rating at End of 2-Hour Overload		Special Purpose Dripproof and All Motors and Generators Other Than Column 1–12 Inclusive Continuous Rated	
Item	Machine Part		Class A Ins. Col. 1	Class B Ins. Col. 2	Class A Ins. Col. 3	Class B Ins. Col. 4	Class A Ins. Col. 5	Class B Ins. Col. 6	Class A Ins. Col. 9	Class B Ins. Col. 8	Class A Ins. Col. 9	Class B Ins. Col. 10	Class A Ins. Col. 11	Class B Ins. Col. 12	Class A Ins. Col. 13	Class B Ins. Col. 14
1	Armature windings and all windings other than 2 and 3	Resistance (see 2.055)			70	100	80	110	90	125		90		110	70	100
		Thermometer (see 2.054)	40		55	75	55	75	55	75	40	60	55	75	50	70
2	Shunt field windings	Thermometer (see 2.054)	40				55	75	55	75	40	60	55	75	50	70
		Resistance (see 2.055)	60		70	90	70	90	70	100	60	90	75	105	70	90
3	Single-layer field windings with exposed uninsulated surfaces and bare copper windings	Resistance (see 2.055)			70	100	80	110	90	120		90		110	70	90
		Thermometer (see 2.054)	50		65	85	65	85	65	85	50	70	65	85	60	80
4	Cores and mechanical parts in contact with or adjacent to insulation	Thermometer (see 2.054)	40				55	75	55	75	40	60	55	75	50	70
5	Commutators and collector rings	Thermometer (see 2.054)	55	75	65	85	65	85	65	85	55	70	65	85	65	85
6	Miscellaneous parts (such as brush holders, brushes, pole tips, and so forth) may attain such temperatures as will not injure the machine in any respect.															

Digest of paper **49-232** "Temperature Rise Values for D-C Machines—Part II," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

Personnel of the AIEE Subcommittee on D-C Machines: T. M. Linville, *chairman;* Mrs. B. O. Buckland, W. E. Clancy, F. A. Compton, Jr., Lanier Greer, L. N. Grier, J. L. Hamilton, C. B. Hathaway, V. P. Hessler, V. B. Honsinger, W. R. Hough, P. Lebenbaum, C. Lynn, L. G. Opel, D. Ramadanoff, J. F. Sellers, B. H. Caldwell, Jr., W. H. Fifer, D. E. Fritz, A. T. McClinton.

Noncontacting Thickness Gauge Using Beta Rays

C. W. CLAPP S. BERNSTEIN

By measuring the energy lost by a stream of beta particles in passing through a sheet of material, the thickness of the material can be determined. Here, strontium 90 was used as the source of beta radiation, and an ionization chamber registered the beta-ray intensity.

AN EARLIER paper[1] has described the use of X rays to measure the thickness of steel as it is being rolled in a hot-strip rolling mill. The great success of this method of measurement has stimulated study of the possibilities of using other types of radiation in a similar manner. Of these, beta rays appear to hold the greatest promise at the present time.

Beta rays are electrons emitted spontaneously by certain radioactive materials. Depending on the nature of the source material, these electrons are emitted with maximum energies varying from a few thousand electron volts up to several million electron volts. Those electrons emitted with high initial energy are able to pass through an appreciable thickness of solid material. For example, an electron with an initial energy of 1.3 million electron volts will lose only one-half of its energy in passing through a sheet of aluminum 0.038 inch thick.

In principle, it is therefore possible to measure the thickness of a homogeneous sheet of material by placing a source of beta rays at a fixed position on one side of the sheet and measuring the number or the energy of the beta rays which pass through the sheet and reach a detector at a fixed position on the other side. Such a thickness gauge has the important advantage of not requiring physical contact with the sheet being measured. The thickness gauge can therefore be used to measure the thickness of soft uncured rubber or plastic, of textiles or paper coated with soft gummy substances, as well as harder materials such as glass, aluminum, and steel.

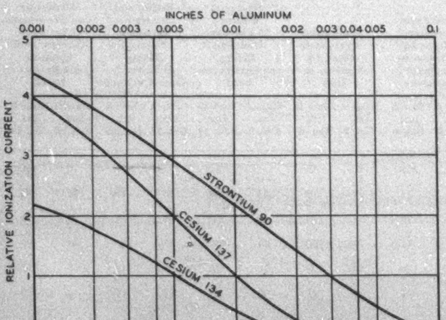

Figure 1. Absorption of beta rays in aluminum

Using an ionization chamber as detector, Figure 1 shows the detector current produced by a beam of beta rays after it had passed through different thicknesses of aluminum. The ionization chamber was filled with air at atmospheric pressure, and was provided with an aluminum window only 0.001 inch thick to allow the rays to enter with the minimum of fixed absorption. The thickness of the aluminum absorber is expressed both in inches and in ounces per square yard. Essentially the same curves are obtained for paper, plastic, or rubber, provided the thickness of the material is expressed in terms of its weight per unit area. Since the absorber thickness has been plotted on a logarithmic scale, the slope of the curve is a measure of the change of ionization current for a given small percentage change in the absorber thickness. The range of thickness over which a particular source can be used effectively is limited at each end by loss in sensitivity as evidenced by flattening of the absorption curve.

The source chosen for the gauge to be described consists of strontium 90.* This material gives off beta rays with a maximum energy of 0.65 million electron volts, and has a half-life** of 25 years. With each emission of an electron, an atom of strontium 90 is converted to an atom of yttrium 90. This product material is in turn radioactive, emitting beta rays with maximum energy of 2.16 million electron volts, and has a half-life of 62 hours. Unlike most radioactive materials, no gamma rays accompany the dissociation of strontium 90 or its daughter yttrium 90. This simplifies measurements of the beta-ray beam and reduces the amount of shielding needed to prevent stray radiation.

An ionization chamber was chosen as the means to measure the energy in the transmitted portion of the beta-ray beam. This detecting means has good stability, does

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Full text of paper 50-73, "Noncontacting Thickness Gauge Using Beta Rays," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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* The intensity of any radioactive source, as measured by the number of particles emitted per second, falls off exponentially with time. The time required for the intensity of any source to fall to one-half of its initial value is called its "half-life."

** This radioactive material as well as others used in this investigation were procured from the United States Atomic Energy Commission at Oak Ridge, Tenn.

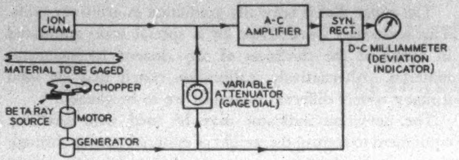

Figure 2. Block diagram of beta-ray thickness gauge

not require high voltages for its operation, and can operate satisfactorily over a wide range of beam intensities. The chamber is filled with air at atmospheric pressure and is sealed to prevent entrance of moisture or other vapors which might adversely affect its operation.

The components of a complete beta-ray thickness gauge are shown in block form in Figure 2. Between the source and the sheet to be measured is a motor-driven chopper or modulator which interrupts the beam 90 times per second. The signal from the ionization chamber is therefore a 90-cycle signal which can be amplified by stable a-c amplifiers, thus avoiding the usual drift problems associated with low-level d-c amplification. To provide an expanded, easily read thickness scale, a potentiometer-type measuring circuit is employed. In this circuit, the output voltage of the ionization chamber is compared with a second 90-cycle voltage of opposite phase which is adjusted in magnitude until the difference between the two voltages is zero. The comparison voltage is derived from a small permanent-magnet alternator driven from the chopper shaft. The attenuator used to adjust the magnitude of the comparison voltage may be calibrated in terms of the thickness or weight per unit area of the material in the beam.

Alternatively, the variable attenuator or gauge dial may be set at the position corresponding to the desired thickness of material to be gauged. The difference between the comparison voltage and the ionization chamber voltage is then a measure of the deviation of the material from the desired thickness.

To read this deviation, the small 90-cycle difference voltage is first amplified by a conventional electrometer tube arrangement. The electrometer tube together with its grid leak and associated circuit components is contained within the sealed ionization chamber to minimize electrical pickup and leakage in the high-impedance portions of the circuit. After further amplification, this voltage is then converted to a direct voltage in a synchronous-rectifier type of detector as shown in Figure 3.

Very briefly, its operation is as follows. A constant reference or switching voltage e_r obtained from the alternator on the chopper shaft is applied through transformer T_1 to two opposite corners of a rectifier bridge. The amplified signal (deviation) voltage e_s is applied through the transformer T_2 to the remaining two corners of the bridge. The reference voltage has an amplitude from two to three times that of the largest signal voltage, and therefore controls the operation of the rectifier bridge.

During the half cycle of e_r when point *A* is positive with respect to *C*, the path *ABC* is conducting and the path *ADC* is essentially nonconducting. During this half cycle therefore, the winding *HF* on transformer T_2 is connected across the load resistance R_L through the two parallel paths *FBAE* and *FBCE*. Similarly, on the next half cycle of e_r, the winding *HG* is connected across R_L through the parallel paths *GDAE* and *GDCE*. If e_s contains any 90-cycle component, a direct voltage will be developed across R_L proportional to the component of e_s in phase with e_r.

The output voltage across R_L is applied to a single-stage d-c amplifier and thence to a d-c milliammeter calibrated in per cent deviation. The output amplifier is capable of driving up to four such instruments for indicating or recording the thickness deviation.

Since the emission of beta particles from the source is a random phenomenon, the strength of the beam is constant only in a statistical sense. The current in the ionization chamber therefore contains a fluctuating noise component analogous to the "shot" noise current in vacuum tubes. To reduce this noise component and permit easier reading of the deviation indicator, a resistance-capacitance type low-pass filter is inserted in the output circuit. Under these conditions, the rms signal-to-fluctuation-noise ratio (for derivation, see appendix) is approximately equal to $\sqrt{2nT}$, where

n = number of primary beta particles entering ionization chamber per second
T = time constant of single-section low-pass output filter

To reduce the effect of random fluctuations in beam intensity, it is apparent that the strength of the source should be as great as possible consistent with economy and safety of operation. Furthermore, the configuration or "geometry" of the gauge should be such that the radiation detector will intercept as many as possible of the emitted beta particles. When this has been done, the time constant of the output filter may be selected to give the best compromise between high speed of response and low random fluctuations of the deviation indicator.

The beta-ray gauge, shown in Figures 4 and 5, consists of three major units; the gauging head, the operator's panel, and a cabinet containing the electronic control circuits. The radioactive source, beam chopper, motor, and

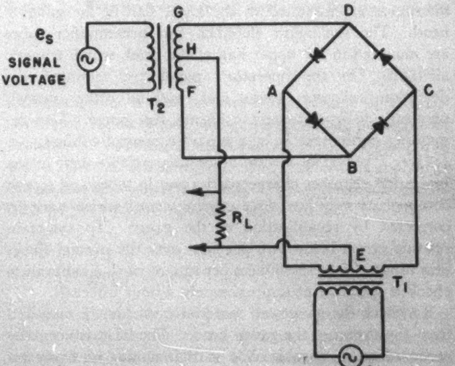

Figure 3. Circuit of synchronous rectifier

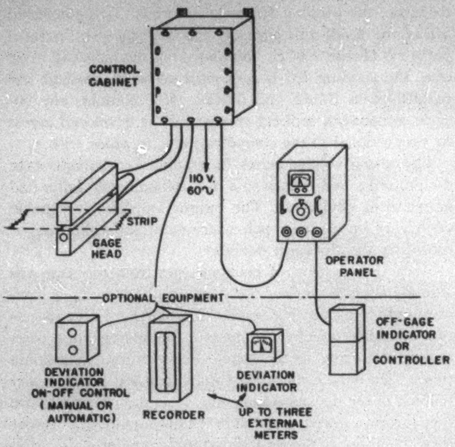
CONTROL CABINET
110 V. 60∿
STRIP
GAGE HEAD
OPERATOR PANEL
OPTIONAL EQUIPMENT
OFF-GAGE INDICATOR OR CONTROLLER
DEVIATION INDICATOR ON-OFF CONTROL (MANUAL OR AUTOMATIC)
RECORDER
DEVIATION INDICATOR
UP TO THREE EXTERNAL METERS

Figure 4. Components (basic and optional) of the beta-ray thickness gauge

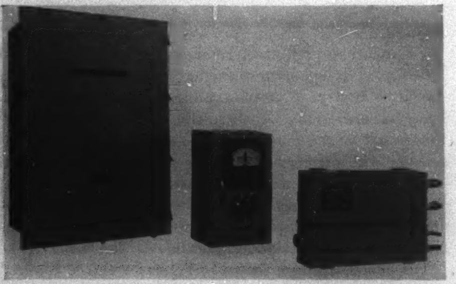

Figure 5. Beta-ray thickness gauge equipment (left to right): control cabinet, operator's panel, gauge head

alternator are mounted in the lower half of the gauging head. The ionization chamber and preamplifier tubes are mounted in the upper half of the head, which is made air-tight. On the operator's panel are mounted the deviation indicator, gauge dial, and all other controls necessary to operate and calibrate the gauge. The remaining equipment is in a separate control cabinet.

Over a period of several hours unavoidable drift in the ionization chamber characteristics and in tubes and circuit components may introduce reading errors which must be corrected by recalibration of the gauge. To maintain reading errors below two per cent over the normal thickness range of 5 to 150 ounces per square yard, a calibration check is specified at approximately 4-hour intervals.

To check the gauge, all material must first be removed from the throat of the gauge head. The head is normally mounted on a movable slide so that it may be easily removed from a process line for this purpose. A test plate is furnished with the gauge for use in checking calibration.

The gauge dial is normally graduated in arbitrary units. This scale may be replaced by a special scale graduated in terms of the thickness of any desired homogeneous material. Alternatively, calibration charts may be used if many widely different materials are to be gauged.

The deviation indicator may be used with auxiliary equipment to control the weight of material passing through the gauge head, or to operate an alarm when the weight exceeds the desired tolerance. Other equipment may be used to return the deviation indicator to zero when there is no material in the beam, allowing more rapid gauging of sections or separate sheets.

Appendix. Calculation of Signal-to-Noise Ratio For Ionization Chamber Current

In the following, it is assumed that the current through the ionization chamber consists of a series of short discrete pulses of constant amplitude randomly distributed in time. Actually, of course, the pulse amplitudes vary through a considerable range depending on the energy distribution in the beam of particles reaching the chamber and on other factors related to the absorption process. The results obtained therefore will be only a first approximation to the truth, and will err in predicting a higher signal-to-noise ratio than is justified.

For constant-amplitude pulses, the equation developed for the shot noise in temperature-limited diodes is applicable and we write

$$i^2=2qI\Delta f$$

where

i = rms noise current (amperes)
q = charge delivered by each constant amplitude pulse (coulombs)
I = average chamber current (amperes)
Δf = noise bandwidth (cycles per second)

Hence

$$\frac{I}{i}=\sqrt{\frac{I}{2q\Delta f}}=\text{signal-to-noise ratio}$$

Since $I=nq$ where n = number of pulses per second in chamber current or number of primary beta particles entering chamber per second, we may write

$$\frac{I}{i}=\sqrt{\frac{n}{2\Delta f}}$$

The noise bandwidth Δf is determined by the transmission characteristic of the output low-pass filter. Let us assume this consists of a single resistance-capacitance section of time constant $T=RC$ seconds. The transmission of such a filter in terms of frequency may be written

$$A=\frac{1}{1+j2\pi fT}$$

hence

$$\Delta f=\int_0^\infty A^2 df=\int_0^\infty \frac{df}{1+4\pi^2f^2T^2}=\frac{1}{4T}$$

Therefore, the signal-to-noise ratio is given by

$$\frac{I}{i}=\sqrt{2nT}$$

Reference

1. An X-Ray Thickness Gauge for Hot-Strip Rolling Mills, C. W. Clapp, R. V. Pohl. AIEE *Transactions*, volume 67, 1948, pages 620–8.

Analysis of Rotating Amplifiers

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MEMBER AIEE

ELECTRIC amplifying devices exist in a number of distinct forms such as electronic, magnetic, and rotating amplifiers, each with a distinct field of usefulness. The rotating amplifier is most prominent where relatively large power outputs are required. However, even rotating amplifiers have been used in the past only as relatively small machines. This article considers the incorporation of amplification in large-sized generators where questions previously neglected must be considered.

These machines take advantage of the fact that it is possible to produce voltage between selected pairs of brush arms on a multipolar commutator machine by exciting particular poles and to utilize these voltages to excite other sets of poles so that amplification can be obtained. In order to make complete use of its capacity as a power generator, all the brush arms are required to carry their normal share of the output load current as they would in a standard machine and, in addition, any required internal circulating currents.

Formulas can be obtained for the reactions which occur in a general *N*-pole structure under unbalanced conditions. A systematic procedure is then set up for selecting the required stator windings to accomplish a given purpose. Where earlier studies had contemplated separate windings for these various purposes, the general technique of combining windings now is known so the same functions can be performed with a small number of windings.

The winding arrangement characterizing the machine can be represented by a stator winding matrix which is a compact pattern of numbers from which differential equations may be set up and the machine behavior obtained.

In order to determine some of the features of the transient behavior of the machines, the transfer characteristics for a number of typical cases can be determined over a range of frequencies. Using suitable dimensionless notation, the transfer expression reduces to the form

$$\frac{I_L}{E_a}=\frac{H}{R_aL}\Upsilon(\rho,\ \alpha,\ T_a) \tag{1}$$

where I_L is the line current, E_a applied control field voltage, H the magnitude, and R_a resistance of the control field winding. L represents the load, and $\Upsilon(\rho,\ \alpha,\ T_a)$ is a function of frequency with α (the amount of machine compensation) and T_a (the control field constant) as parameters. Curves for $\Upsilon(\rho,\ \alpha,\ T_a)$ are plotted for both amplitude and phase angle in Figure 1.

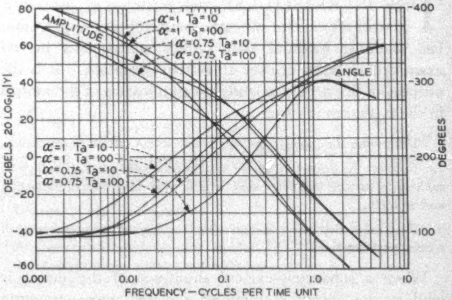

Figure 1. Transfer curves—magnitude and angle of the transfer function

The transfer curves for the 4-pole structure may be employed to determine transient behavior for comparison with test data. The case considered is that in which the rotating amplifier is used to control the voltage of a turboalternator. The output voltage (proportional to alternator field current) is rectified and a fraction of it, K, is compared with a reference standard, E_o. The difference is applied to the control field which then corrects the voltage. There results for the transfer expression with feedback present:

$$I_L=\frac{E_o}{K}\,\frac{.1}{\left(1+\dfrac{LR_a}{H\Upsilon K}\right)} \tag{2}$$

Figure 2 shows a calculated time response to unit step voltage change in the control field together with an actual test curve for this case. The agreement is seen to be fairly good. The fact that the error is still moderately large is to be expected from the nature of the calculation.

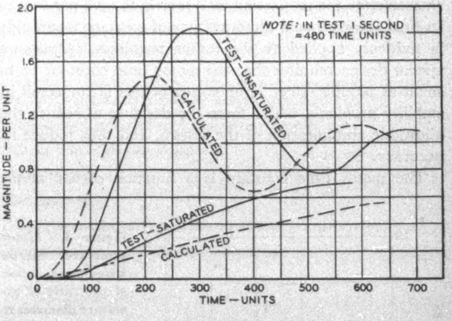

Figure 2. Transient response of machine—calculated and test values

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Digest of paper 49-231, "An Analysis of Rotating Amplifiers," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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D-C Motors for Automatic Control Systems

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THE INCREASED USE and accuracy of automatic control systems for industrial and military applications has made it essential that system components be re-examined in terms of over-all system operation. It is the purpose of this article to study the application of d-c motors in these systems in order to

1. Determine the motor constants which affect system performance.
2. Convert the important motor system constants into design factors, such as armature diameter and length, flux and copper densities, and so forth.
3. Determine the motor design which will give optimum over-all system performance.

When a separately-excited shunt-wound d-c motor is used as the output member of a closed-cycle automatic control system, the motor time constant is the motor constant which the system designer uses in calculating the stability, allowable amplification, accuracy, and speed of response of the system. It is defined as the time in seconds to accelerate the motor and load inertia to 63.2 per cent of its final speed when a direct voltage of constant magnitude is suddenly applied to the motor terminals. Optimum system design requires that the motor time constant be as small as possible, since large values of this factor result in stability problems, which force the designer to reduce the allowable amplification of the system, and thus reduce its accuracy.

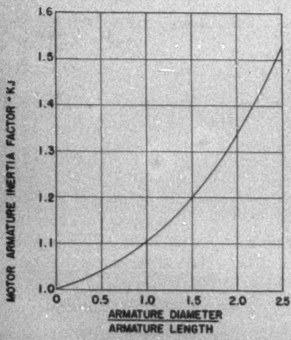

Figure 1. Motor armature inertia factor as a function of the ratio of armature diameter to length, for a line of 4-pole commutating-pole 1,750-rpm motors, ranging in size from 5 to 60 horsepower

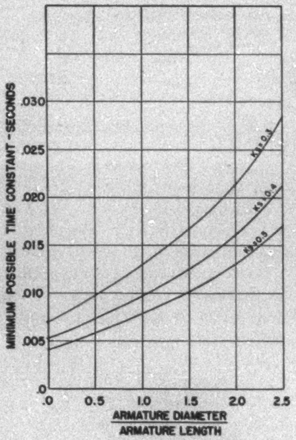

Figure 2. Minimum possible motor time constant as a function of the ratio of armature diameter to length, for a line of 4-pole commutating-pole 1,750-rpm motors, ranging in size from 5 to 60 horsepower

Negligible load inertia, one commutating field circuit, commutating field to armature copper density ratio of one-half, and 1.15 compensation

The motor time constant is a function of the motor armature circuit resistance, the inertia of the motor and the load, and the torque and generated voltage constants of the motor. When this constant is converted into motor design terms, it is found that it is primarily a function of the motor pole face flux density; the flux density at the root of the armature tooth; the ratios of armature slot depth to diameter, and the pole arc to pole pitch; and the ratio of commutating field to armature conductor copper densities. A study of the mathematics of the problem reveals that the following points should be considered in designing a motor with a minimum time constant:

1. The flux density at the root of the armature tooth should be high.
2. The armature slot depth should have a value as close to one-eighth of the armature diameter as possible.
3. The ratio of pole arc to pole pitch should be large.
4. The ratio of armature slot copper area to armature slot area should be high.
5. The ratio of commutating field to armature conductor copper density should be small.
6. The ratio of armature diameter to length should be small, when the load inertia is negligible (see Figure 1). When the load inertia is not negligible, an increase in this ratio may actually give a smaller motor time constant. Under this condition a larger value of the ratio may result in a greater decrease in armature circuit resistance than the corresponding increase in motor and load inertia, and thus in a net decrease in time constant.

Figure 2 is a plot of the minimum possible motor time constant for a line of 4-pole commutating-pole 1,750-rpm motors, ranging in size from 5 to 60 horsepower, having negligible load inertia. K_s is the ratio of armature slot copper area to armature slot area. This curve indicates substantial reductions in time constants over those obtainable with standard general purpose motor designs.

Digest of paper 49-225, "The Design of D-C Motors for Use in Automatic Control Systems," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17-21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Diagnosis of Rectifier Ailments

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THE MERCURY-POOL rectifier is a thoroughly reliable machine when properly protected and applied with the understanding that it is subject to infrequent, randomly occurring, internal faults known as arc-backs. An arc-back is a failure of an anode to block the flow of current from cathode to anode, resulting in a unidirectional short circuit between that anode and all normal anodes.

Unlike other electric machinery, a rectifier in perfectly sound condition and normal environment may fail momentarily, and if cleared quickly by its protective gear, return immediately to normal service. The probability of arc-back expressed in anode-cycles is extremely slight, many rectifiers averaging less than one in 23 billion (one year of service at 60 cycles for a 12-anode rectifier).

The probability of arc-back is increased by almost anything that goes wrong in the rectifier unit, including certain important auxiliaries, and sometimes it is affected by abnormalities in the connected a-c and d-c systems.

Damage from one arc-back to a properly protected rectifier is almost negligible, but some of the effects are cumulative and tend to increase the arc-back rate beyond the original cause.

Opening the rectifier for inspection is no more justifiable as a first step than exploratory surgery in the case of a human patient. There is no assurance before diagnosis that the trouble is internal, nor that the cause will be found without definite clues to guide the search.

It is well to consider the arc-back as a very noticeable but transitory symptom of some more insidious and persistent ailment. Other than the knowledge that an arc-back has occurred, and sometimes that is not certain, not much else can be gleaned from that fact without special apparatus. It is logical then, as a first step, to gather and analyze all information made available by organic instruments and devices such as load current and voltage, overload relay targets, annunciator targets, vacuum (and seepage rate test when opportune), rectifier temperature, transformer temperature, phase-angle control, and excitation current.

The most significant symptoms are deviations from normal of any of the indications given in the foregoing and following lists. Particularly important is dissymmetry among anodes and grids, requiring for detection the use of magnetic links, clip-on ammeter, megger, and cathode-ray oscilloscope. This equipment is not expensive and should be on hand in any important installation. Of the observations listed below, only the first requires a shutdown.

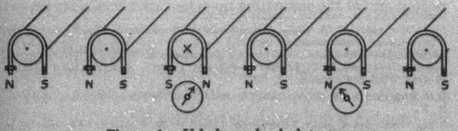
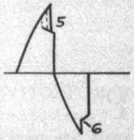


Figure 1. U-bolt arc-back detector

Figure 2. Interphase transformer voltage, showing erratic pickup of anode 5



1. Internal insulation resistances.
2. Anode current balance.
3. Arc-back distribution among anodes.
4. Anode-to-cathode voltage wave shape.
5. Anode current wave shape.
6. Grid-to-cathode voltage wave shape.
7. Grid current wave shape.
8. Interphase transformer voltage wave shape.

While the sequence of performing the various tests is determined largely by local conditions and requirements of service, the following outline will serve as a guide for determining the procedure. The findings at any one step may alter the sequence of subsequent steps.

1. Ascertain that interruptions are actually being caused by arc-backs. A U-bolt detector may be used for this (Figure 1).
2. Check distribution of arc-backs among anodes.
3. Check anode current balance.
4. Megger test.
5. Seepage test.
6. Check operation of interphase transformer and wave shape.
7. Check wave shapes of the following items:
    a. Anode-to-cathode voltages.
    b. Anode currents.
    c. Grid-to-cathode voltages.
    d. Grid currents.
8. Detailed investigation of nature of arc-backs, including oscillograms obtained at the time of arc-back by means of an oscilloscope and automatic camera. Oscillograms such as those shown in Figure 2 may be discovered.
9. Investigation of a-c and d-c circuits.
10. Open tank or tanks for inspection and overhaul.
11. Check circuit-breaker and relay speeds before restoring unit to service to make sure that slow tripping will not cause further deterioration.

The order is not fixed and of course the procedure is terminated at any point when it is felt that the trouble has been definitely diagnosed. Opening the tank may or may not be necessary. Before restoring the unit to service, checking of circuit breaker and relay operation should be made a matter of routine.

Digest of paper **49-270**, "Diagnosis of Rectifier Ailments," recommended by the AIEE Committee on Electronic Power Converters and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Relay Protection for Medium-Length Transmission Lines

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The relay elements available for building an adequate protective scheme have improved and become more numerous as needs have increased. The second in a series* of three articles on the protection of high-voltage transmission lines, this article is a description of the standard relays for medium-length high-voltage transmission lines available from manufacturers today and describes their uses in a typical system.

PROTECTIVE relaying development over the years has produced a wide choice of equipment varying from simple instantaneous current types to more complicated directional and impedance types. The ingenuity of relay engineers has produced a still wider choice of methods of applying the various types of relays which are available. It is the purpose of this article to discuss the various types of relay protection which are applicable to medium-length high-voltage lines and, using a typical system as an example, examine some of the advantages and disadvantages which are inherent in them. In order to limit the discussion to reasonable length it will be confined to types of relaying available as standard equipment although the possibility of special schemes for special purposes must be recognized.

DESCRIPTION OF TYPICAL SYSTEM

Figure 1 shows a hypothetical system selected to represent a range of conditions frequently encountered. It is assumed to be a predominantly steam-driven system where transmission line loading can vary considerably depending upon the location at which power can be generated economically or upon what generating units are out of service for either scheduled or emergency maintenance. The system is simplified to the extent that elements not essential to the problem of protective relaying have not been shown.

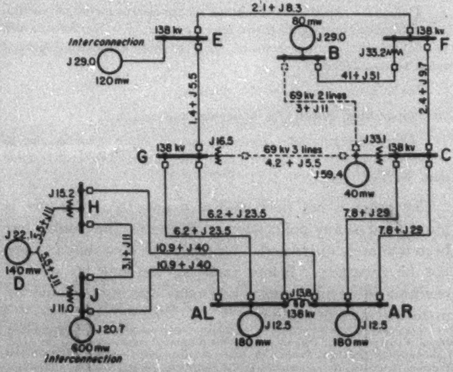

Figure 1. Typical system; positive sequence impedance per cent on 138,000-kva base

The lines from Station *A* to Stations *G* and *C* are respectively 40 and 50 miles long and are typical medium-length lines. They have to meet sufficiently similar conditions so that their required relay protection is identical. Therefore, the discussion will be confined to lines *AL* to *G*.

Figure 2 shows a typical heavy loading condition on these lines such as can be expected with generators at *B* and *C* out of service. It represents about as heavy power transfer as can be expected from Station *A* to Stations *G* and *C* for any except emergency conditions. Figure 3 shows 3-phase short-circuit values for the various station busses.

Transient as well as steady-state conditions must be considered. A permanent 3-phase fault on lines *AL* to *G* during which they are tripped, reclosed high speed, and retripped would represent about as severe a condition as the relays on lines *AR* to *C* might be called on to handle. Figure 4 shows the power-angle-swing curves for this condition with the heavy initial loading of Figure 2. Figures 5 and 6 show the impedance seen by relays at the two ends of the line during the oscillations caused by such a fault. The circles represent suggested relay operating point loci as will be discussed in this article.

GENERAL OBJECTIVES

The objective of this study will be to provide the best type of relaying available with ability to meet all expected conditions being given first consideration and cost being taken into account after technical requirements have been met. This is considered justified by the importance of the four lines in question which under certain conditions are expected to carry a total of about 300,000 kw (Figure 2). This relaying must be reliable and fast in operation. It must be capable of clearing minimum fault currents expected and at the same time must be capable of carrying the

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Full text of paper **50-68**, "Relay Protection for Medium-Length High-Voltage Transmission Lines," recommended by the AIEE Committee on Relays and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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* See "Protection of Short Transmission Lines," by W. E. Marter (*EE, Mar '50, pp 915–19*).

heaviest load currents and transient swings to be expected without any false tripping.

ADVANTAGES OF 1- TO 2-CYCLE RELAYING

The advantages of obtaining the fastest possible tripping time for faults at any point on the protected lines are well known. Those most commonly mentioned are

1. Reduction of short-circuit damage with consequent increased chance of re-energizing the line immediately.
2. Minimization of the objectionable effects of voltage dips on customer's motors.
3. The ability to carry higher loads without loss of synchronism because of short circuits.
4. The ability to employ ultrahigh-speed reclosing (20 cycles or less) and so increase the maximum loading which can be carried safely.

Pilot wire or carrier relaying schemes must be employed to obtain this speed, for they are the only types of relaying currently available which do not require graded time settings to insure selectivity with relays on adjacent line sections. Without examining the problem in detail it is evident that the line lengths involved make pilot wire relaying uneconomical and therefore it will be disregarded.

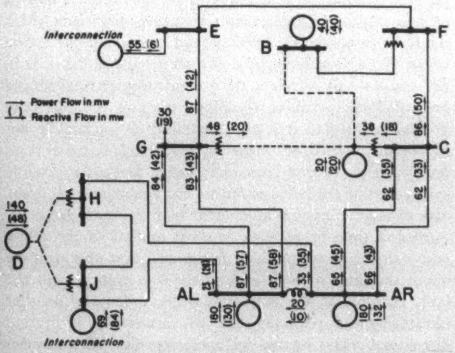

Figure 2. Heavy loading conditions on lines *AL* to *G* and *AR* to *C*

For lines as heavily loaded as these the ability to re-energize immediately after a flashover is of considerable importance. The loss of one line produces heavier loading on the remaining three, and although these lines are capable of carrying this loading, the increased line losses and poorer voltage regulation at intermediate stations might be sufficiently objectionable so that the amount of power interchange would have to be reduced. These objectionable conditions could be minimized still further if ultrahigh-speed reclosing were employed, because in about 90 per cent of the cases it would permit the line to be restored to normal before any objectionable voltage conditions could appear on the system. The advantages of reclosing at once are even more pronounced if one line is assumed out of service and a fault occurs on a second line.

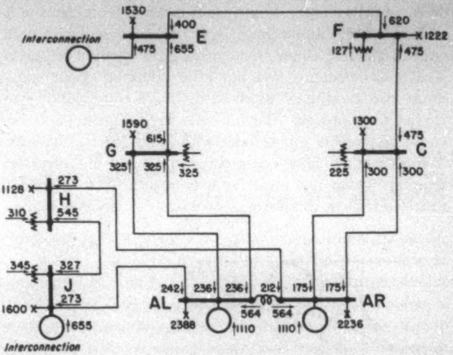

Figure 3. Three-phase fault distribution in megavolt-amperes

Faults on an extensive high-voltage system of this sort are usually reflected in voltage dips over a considerable geographical area which may affect service to a large number of industrial customers. While modern practice provides time-delay undervoltage protection for industrial motors to prevent their loss during momentary voltage dips, there are sometimes heavily loaded synchronous motors which can lose synchronism during relatively minor system disturbances. High-speed fault clearing helps to prevent this loss of synchronism. Data are not included for a detailed analysis for the system under consideration and generally such analyses are not worth while unless inspection discloses cases which may be critical. There are usually some such individual instances but their extent and importance cannot be evaluated here.

A transient stability study of the system (Figure 4) shows that a double-line 3-phase fault at *AL* on the lines from *AL* to *G* can be tripped, reclosed into the fault in 20 cycles, and retripped without loss of synchronism over lines *C* to *AR*. This shows the system to be quite stable under heavy load and severe fault conditions, and demonstrates that from this standpoint 20-cycle reclosing is unnecessary. However, it further shows that 20-cycle reclosing will not be instrumental in causing loss of synchronism when reclosing into a permanent fault.

CARRIER-CURRENT RELAYING

These considerations lead to the conclusion that carrier relaying is justified and should be installed on these lines for the increased chance it offers of keeping the lines in service with the consequent improvement in general system voltage conditions and reduction of system losses. Furthermore, with carrier relaying installed, ultrahigh-speed reclosing can be employed at practically no additional cost and should be used for the same reasons. Further justification is found in the improvement to customer's service and in the increase in permissible loading limits which may be of value under possible emergencies or as loads grow in the future.

Carrier relaying, in common with any other type, must be capable of tripping under minimum short-circuit conditions. Furthermore, if maximum speed of fault clearing is to be attained, this minimum must be determined with both ends of the line closed so as to avoid sequential tripping. The fault-detector relays should not pick up under maximum load conditions because this would cause continuous carrier transmission. This is considered objectionable because of possible interference with other carrier channels. Tripping relays must not pick up because while incorrect tripping would not result as long as carrier transmission continued there is always danger of it if any momentary interruption to transmission or reception should occur. Keeping these limitations in mind, phase comparison and directional comparison using impedance-type relays, which are the two types of carrier relaying in common use, will be considered.

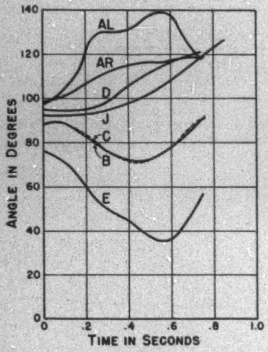

Figure 4. Power-angle-swing curves; simultaneous 3-phase faults on lines *AL* to *G*, both lines reclosed and retripped

Phase-Comparison Carrier. Phase comparison is essentially a simple overcurrent-type of relaying in that its tripping and carrier-starting points are determined entirely by current measurement. Considering the lines from *AL* to *G* the maximum indicated load is about 430 amperes, and if one line were out, it would probably be above 600 amperes. For a 3-phase short circuit at *AL* with the system normal, 990 amperes flows over each line from *G* (Figure 3). To insure that carrier not be transmitted continuously the starting relay should have a pickup not lower than 600 × 1.5 = 900 amperes. If it is considered that this loading is of sufficiently infrequent occurrence as to be neglected, the starting relay can be set at 430 × 1.5 = 645 amperes. The tripping relay should be set at least 25 per cent above the starting relay to insure co-ordination which gives at least 806 amperes. This value is dangerously close to the minimum short-circuit value of 990 amperes and leaves no margin for the further reduction of this value which will occur when system conditions are abnormal. Furthermore, there is no chance of handling heavier loads, should they develop. If only a negative phase sequence network is employed the setting becomes independent of load current, but the relay would then be incapable of operation on 3-phase short circuits. For these reasons phase-comparison carrier relaying does not appear adequate.

Directional-Comparison Carrier. Directional-comparison carrier relaying using conventional reactance- or impedance-type relays for carrier starting and tripping will avoid some of the objectionable features of a simple overcurrent scheme. For discussion purposes an impedance-type relay will be considered. Line *AL* to *G* has an impedance of about 24 per cent. It is generally considered conservative practice if the carrier-tripping relay impedance setting be made 50 per cent higher than the line impedance, which would be 36 per cent. The carrier-starting relay impedance should be at least 25 per cent higher than the tripping relay, which would amount to about 45 per cent. This setting would correspond to about 1,280 amperes at normal voltage, which is an adequate margin over the maximum expected load current of 600 to 700 amperes. It, therefore, appears that directional comparison using impedance- or reactance-type relays can protect adequately against minimum faults and still handle maximum loads without incurring continuous carrier transmission. It is obvious, therefore, that the mho and modified-impedance types also would cover the conditions with probably an even greater safety margin.

The ground relaying for carrier should be provided with a separate ground directional relay, either current or potential polarized, and arranged in the conventional way to provide ground preference type of operation. This is necessary to avoid any possible incorrect operations which might be caused by the effect of load currents on the action of the phase-directional relay during ground faults. As in the case of the phase relays, the ground-tripping relay should be sufficiently sensitive to insure tripping on minimum ground faults, and it is suggested that the pickup be not higher than one-third of the minimum calculated ground fault so it provides a reasonable safety factor for possible impedance at the point of fault. Furthermore, it is desirable that at minimum calculated fault currents the relay operating time be at least as short as that of the phase relays under phase-to-phase faults and that this time be about the same at both ends of the line even though the fault currents at the two ends differ materially so that ultrahigh-speed reclosing can be successful. If ground directional relays having an operating time which varies with torque are used, it may be necessary to make the setting even more sensitive than the value suggested previously to insure that operation is on the flat part of the timing curve at minimum fault currents.

PHASE BACKUP RELAYING

Although the primary carrier relaying can be expected to clear all faults in the protected line section under normal conditions, backup relaying is still required for a number of reasons. There are times when the carrier must be taken out of service for repair or calibration. Occasionally conditions arise, such as sleet formation on the conductors, when the carrier signal cannot be received. If an oil circuit breaker should fail to trip on a faulty line section, some means is needed for tripping adjacent sections. Tie lines between generating stations sometimes must be tripped under out-of-step conditions. Backup relaying must be provided to obtain as many of these features as possible.

The choice of backup relaying may be influenced by the type of backup relaying employed generally on the system. It must co-ordinate properly with the relays on the adjacent lines. Generally speaking, impedance or reactance-type relays can be made to work successfully with inverse-time-induction types, and it will be assumed that this can be done in this case. Whatever type is chosen should be designed to clear faults as fast as possible while still retaining adequate selectivity with backup relays on adjoining line sections. Impedance or reactance relays with definite time settings and induction overcurrent combined with plunger-type instantaneous overcurrent will be considered.

Three-Step Impedance Relaying. Impedance-type relays with the conventional 3-step arrangement for phase protection would be subject to the same limitations in sensitivity and load-carrying ability as those outlined for carrier relaying. For the lines from *AL* to *G* at *AL* the first, or instantaneous, tripping zone could be set to cover about 90 per cent of the line. The second zone must have a time setting selective with the protective relays on the other outgoing lines and with any time-delay transformer or bus differential relays at *G*. The worst condition would probably be selectivity with the relays on the line from *G* to *E*. The total line impedance from *AL* to *E* is about 30 per cent, which is only about 25 per cent greater than the impedance of line *AL* to *G*. If the second zone setting is not to reach beyond *E*, this would give an impedance setting with a rather narrow safety margin. However, with the system normal and a fault at *E* the apparent impedance seen by the relays at *AL* is much higher than 30 per cent. Even with one line out from *AL* to *G* this is true because of the effect of the lines from *G* to *C*. Furthermore, it is assumed that line *GE* will have carrier or pilot-wire relaying for primary protection so that its relay time will normally be one to two cycles and that all lines out of *E* will have 1-cycle relaying for faults near *E*. Since it is unreasonable to assume that the second line from *AL* to *G* and the lines from *G* to *C* will all be out at the same time a fault occurs close to *E* which the fast relaying of *E* or the pilot wire relays on *GE* fail to clear, it is justifiable to make the impedance setting at *AL* at least 35 per cent, which gives a 50 per cent safety margin for faults near *G*. A study should be made to make sure this does not overreach *E* with the second *AL*-to-*G* line out.

The third zone setting, which would correspond to the carrier-starting relay, could be set for an impedance of 48 to 50 per cent as outlined for the carrier relaying which would be well above maximum load impedance as well as above maximum impedance seen by the relays during a transient swing. This transient swing condition has not been analyzed accurately, but it may be estimated by examining Figure 5 which shows the conditions on lines *AR* to *C* for permanent trouble on both lines from *AL* to *G* with 20-cycle reclosing. A similar analysis can be employed for the relays at *G* except that in this case the third zone impedance setting cannot be made high enough to reach to Station *J* with the system normal, and any backup protection to cover oil circuit breaker or relay failure of *AL* would have to be provided by a scheme installed at Station *AL*.

Simple Overcurrent Relaying. If time-delay induction overcurrent combined with plunger-type instantaneous relays were employed on *AL* to *G*, their limitations would be similar to those outlined for phase-comparison carrier relays. The instantaneous relays at both ends could be set easily to cover 90 per cent of the line length. At *G* their tripping would have to be controlled by a directional relay. The time-delay relays at both ends would have to be set above 900 amperes to prevent operation on heavy load currents with one line out. However, it is not necessary that they operate on minimum fault conditions with all lines in but merely that they operate with a reasonable safety margin after the opposite end has opened.

For a fault at the end of one line to *G* the current from *AL* would be about 2,000 amperes after the circuit breaker at *G* has opened. Since this is based on maximum generating conditions and all lines normal except the one in trouble, it is a rather narrow safety margin over the 900-ampere pickup setting. A voltage control scheme might be introduced which would prevent the overcurrent relays from operating unless the voltage dipped, thereby permitting the current pickup to be reduced to about 600 amperes. For the same fault condition the voltage at *AL* would be about 80 per cent and the voltage control device would have to be set to drop out at 90 per cent, which is dangerously close to the normal operating point. This narrow margin might be tolerated, but future expansion would reduce it still further and it appears preferable at *AL* to employ impedance relays where a satisfactory margin exists.

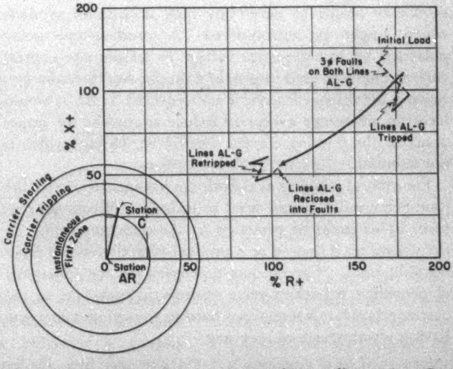

Figure 5. Impedance locus seen by relays on lines *AR* to *C* at *AR* for simultaneous 3-phase faults on lines *AL* to G near *AL*

For a fault at the end of one line to *AL* from *G* the current at *G* would be about 1,600 amperes with the circuit breaker at *AL* open. Again, this is an inadequate margin over the pickup setting of 900 amperes. However, in this case voltage control could be used satisfactorily since the voltage at *G* would dip to about 65 per cent. Likewise, directional control could be used since normal heavy power flow is always from *AL* to *G*. Either scheme has the advantage of providing a backup relaying scheme independent of the carrier relaying. Since a directional feature is required with the backup relaying at this point the carrier

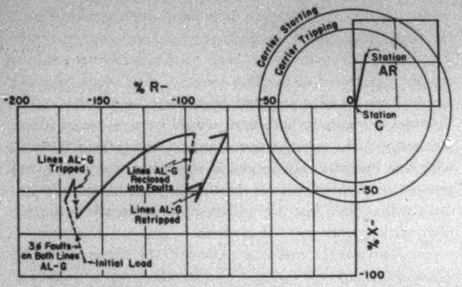

Figure 6. Impedance locus seen by relays on lines *AR* to *C* at *C* for simultaneous 3-phase faults on lines *AL* to *G* near *AL*

directional relay could be common to both schemes if desired and would result in some reduction in cost. Voltage control is suggested in this case primarily because the same voltage relays can be used for the other lines at the station, and therefore it will be the more economical setup.

Ground Backup Relaying. For ground relaying at *AL* an instantaneous, plunger-type relay set to pick up at about 105 to 110 per cent of the ground current in the line for a fault at *G* with the parallel line out can be employed. An induction overcurrent relay set to pick up at about one-third of this same short-circuit current can be used to cover faults below the pickup of the instantaneous relay. The pickup value of one-third of a solid fault at the far end of the line should be ample to cover any high impedance grounds which might be encountered. A product-type relay polarized by zero-sequence voltage or transformer-neutral current might be used instead of a simple overcurrent relay. Since a directional feature is not required at *AL* it would have no advantage except to reduce somewhat the impedance in the bushing current transformer circuit, which is not essential.

For ground relaying at *G* both the instantaneous and the time-delay relays would need to include a directional feature. This could be provided by the directional relay in the carrier set if desired or a product-type time-delay relay could be used. The product-type relay has the advantage of providing a backup relay entirely independent of the carrier relays but is sometimes hard to co-ordinate on a line having ultrahigh-speed reclosing.

BALANCED PROTECTION

Since the two lines in question have equal impedance and terminate on common busses at each end, it would be possible to employ balanced-protection phase and ground relays at both ends. These compare the currents in the two lines and operate to trip the line in trouble when its current exceeds that in the other line by a predetermined amount or percentage. Power directional measurement is included at stations not a source of short circuit current. Since there is no problem of selectivity with relays on adjacent line sections they can be instantaneous in operation. They would operate in one to two cycles for single circuit faults over 80 to 90 per cent of the line and for the remainder of the line would operate sequentially after the other end had tripped. They would also operate for some cases of simultaneous trouble on different phases of the two lines when the impedance relays might measure a false impedance. For single-line phase-to-phase faults beyond the instantaneous zone of the impedance relays they should shorten the total clearing time because, even with sequential tripping, the total time would probably be shorter than the time of the second zone of the impedance relays. For ground faults in a similar location sequential instantaneous tripping would probably occur from the instantaneous ground relays because there is an increase in ground current after the near end has tripped which will permit the relay at the far end to pick up. Similarly, for simultaneous faults on different phases of the two lines there is a good chance that the instantaneous ground relays will operate, even for the infrequent case when these faults do not involve ground.

It therefore appears that tripping time is shortened only for phase-to-phase faults in the last 10 per cent of the line which is 20 per cent of the faults not involving ground. If 90 per cent of the faults involve ground (this depends on line construction and other physical factors), then improvement is obtained in only 0.10×20 per cent $= 2$ per cent of the total cases of trouble. Since the improvement obtained of perhaps 0.3 second faster clearing is not a critical factor in system performance and the cases of trouble covered are so few, it is doubtful whether these relays are justified. When carrier relaying is used as primary protection the value of balanced relaying becomes insignificant.

RELATIVE COSTS

In order to give some idea of the relative costs of the various types of relaying discussed, the installed cost of directional comparison carrier using impedance or reactance relays has been assumed to be 100 per cent. This includes the capacitor, transmitter-receiver, line trap, relays, cable for transmitter-receiver, installation labor, and overhead. The relay setup available as standard equipment includes impedance backup and any type of ground backup required. On this basis the installed costs of other type would be approximately as follows:

Modified-impedance or mho-type carrier		100 per cent
Phase Backup	Added cost for 3-step impedance backup (phase only)	0 per cent
	Added cost for time and instantaneous overcurrent with voltage control and using carrier phase directional relay	6 per cent
	Added cost for directional controlled phase overcurrent using self-contained single-phase directional relays and instantaneous overcurrent controlled by carrier directional relay	8 per cent
Ground Backup	Added cost for time and instantaneous overcurrent ground relay	0 per cent
	Added cost for product type time and instantaneous overcurrent ground relay	0 per cent
Balanced Protection	Added cost for high-speed current-balance relay	11 per cent

These figures indicate that a small additional premium must be added to the cost of a standard carrier relaying setup to obtain a phase-backup setup using relays separate from those employed for the carrier. However, it is possible to employ special relays for carrier which have only the features which are needed for the carrier functions at a considerably reduced cost. This can be combined with separate 3-step impedance backup at a total cost about three per cent higher than that of a standard setup. In any case the relaying is a small proportion of the total value of the line being protected and is even a small proportion of the cost of the remaining terminal equipment such as circuit breakers and disconnect switches. Once carrier relaying has been decided on, the choice of backup protection on important lines can be based almost entirely on technical considerations. Further, the relatively small cost of carrier as compared with the equipment and service which it protects makes its selection likewise dependent primarily on the technical advantage which it offers on important lines. Since the dollar cost of carrier goes down only a small percentage on lower voltage lines and that of backup relays not at all, economic factors assume greater importance as the voltage and importance of the lines involved decreases.

From this standpoint there is an important field of development open for relaying schemes, including carrier, which will provide high-speed, accurate tripping at sufficiently reduced cost to justify their use on low-voltage lines.

CONCLUSIONS

A summary of suggested relay protection is as follows:

Primary Protection.

Directional comparison carrier current relaying using impedance-type phase relays and ground preference scheme.

Backup Protection.

At AL and AR.

Phase protection: 3-step impedance relays.

Ground protection: simple instantaneous plunger relays and inverse time-induction relays.

At G and C.

Phase protection: simple instantaneous plunger-type relays, inverse time-induction overcurrent relays with voltage control using the carrier directional relay.

Ground protection: simple instantaneous plunger-type and inverse time overcurrent relays using the carrier directional relay.

The elements available for building up an adequate protective scheme have multiplied and improved as the needs have grown, and we have every right to expect that this progress will continue. Advantage of special arrangements to cover special situations must be taken by the relay engineer, but in making such applications the effect of changing conditions due to system expansion always must be kept in mind. These suggestions are based on standard equipment available which is suitable for the system involved and will provide fast, reliable protection insensitive to maximum load currents and transient swings.

Reciprocal Aspects of Transient and Steady-State Concepts

W. J. KESSLER

The transient response of a network can be defined in steady-state terms, and the steady-state behavior can be described in transient terms. The steady-state behavior is usually defined in terms of amplitude and frequency while the transient behavior is defined in terms of amplitude and time. Therefore, the transient and steady-state responses are regarded as nothing more than alternative viewpoints of network behavior when it is expressed in the time domain or the frequency domain respectively.

IT IS well known that the transient response of a network can be specified completely in terms of its steady-state behavior and vice versa. This is one of the most significant interpretations attached to the Fourier and Laplace transformations as applied to the study of electric networks. Actually, the steady-state and transient concepts are regarded as alternative viewpoints of network behavior as expressed in the frequency and time domains respectively.

It is the purpose of this article to stress the viewpoint that these two concepts are reciprocally related and to suggest that the Heaviside step function may be regarded as a standard frequency variation analogous to sinusoidal functions as standard time variations. The factors underlying the choice of sinusoidal and cosinoidal functions as fundamental time variations are also considered briefly.

Conventionally, transient and steady-state concepts are employed to specify the behavior of electric networks over different intervals of time. Transient concepts are applicable during those time intervals when the response of a network is determined almost entirely by its natural or

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force-free behavior, that is, during the sudden application or removal of the driving forces or voltages. Steady-state concepts, however are applicable only during those intervals when the network response is entirely under the influence of the driving forces.[1]

For mathematical purposes, the steady-state condition is specified by stating that the network has been under the influence of the driving forces since a time t equal to minus infinity and will continue to be so until a time t equal to plus infinity. From a practical standpoint, it is necessary only that the network remain under the influence of the driving forces long enough to permit the transient characteristics to become negligible in order to classify the behavior as steady-state. The foregoing ideas have become so deeply ingrained in the thinking of engineering students that they may not be fully aware of the reciprocal relationship which exists between the conventional transient and steady-state concepts.

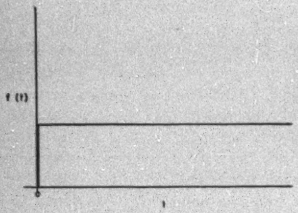

Figure 1. Graphical representation of unit step function in the time domain

As a brief restatement and introduction, steady-state concepts are usually associated with the amplitude response of networks as a function of the frequency which is involved, while transient concepts are associated with amplitude response as a function of time. Therefore, the reciprocal relationship of transient and steady-state concepts is based completely on the reciprocal nature of time and frequency.

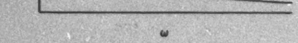

Figure 2. Graphical representation of unit step function in the frequency domain

DETERMINATION OF STEADY-STATE BEHAVIOR

The steady-state behavior of an electric network is determined by impressing a standard time variation across the input terminals of the network and observing the output response as a function of frequency. The standard time variation is usually of sinusoidal or cosinoidal form. The basic factors underlying the choice of sinusoidal and cosinoidal wave forms as the fundamental time variations may be outlined as follows:[2]

1. The time derivatives and integrals of sinusoidal and cosinoidal time variations are identical in form.
2. Sinusoidal, $f(t)$, and cosinoidal, $g(t)$, time variations are mutually orthogonal functions; that is, they satisfy the expression

$$\int_a^b f(t)g(t)dt=0 \tag{1}$$

over the interval ab, thus greatly simplifying the determination of the Fourier coefficients.

The physical significance of statement 1 is recognized when considering the relationship between the current and voltage in inductive and capacitive networks. Since $e=Ldi/dt+Ri$ in inductive networks and $e=(1/C)\int idt+Ri$ in capacitive networks, the amplitude characteristics of any other known time variations would be modified in an unpredictable manner unless the nature and magnitude of the resistive and reactive network components were known beforehand.

The practical significance of statement 2 is based on the fact that the use of a fundamental time variation other than one which is a sinusoid or cosinoid as the elementary building block of a Fourier-type expansion would render the analytical determination of any one coefficient virtually impossible since the remaining terms would not reduce to zero.

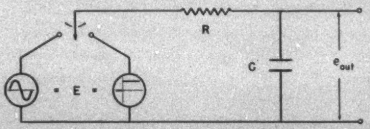

Figure 3. Equivalent circuit of resistance-capacitance passive network to show the application of the equivalent frequency function

DETERMINATION OF TRANSIENT BEHAVIOR

The transient behavior of an electric network is usually determined by impressing an abrupt test signal across the input terminals of the network and observing the output response as a function of time. The abrupt test signal may be any periodic function of known Fourier transform or the nonperiodic Heaviside unit step function. Of the many functions (rectangular waves, saw-tooth waves, and so forth) which are known and are useful in the transient analysis of networks, perhaps the simplest to generate is the Heaviside step function shown in Figure 1. This step function may be readily generated with a d-c source of appropriate magnitude and a switch for applying the pulse at any convenient time. The transient behavior of any network under consideration is usually determined by observing the response as a function of time throughout the transient interval. The end of the transient interval is indicated by changes in response which are no longer significant.

The time function shown in Figure 1 may be defined mathematically as follows:

$$f(t)=\begin{cases}0 \text{ when } t<0\\ 1 \text{ when } t\geqq 0\end{cases} \tag{2}$$

It is observed that this is a discontinuous function of time subject to the usual mathematical difficulties. Application of the Laplace transformation yields, after simplification, the equivalent frequency function

$$g(\omega)=\frac{1}{\omega} \tag{3}$$

Figure 2 is a representation of this transformed function which is continuous over the range normally encountered.

ILLUSTRATIVE EXAMPLE

As an example showing the application of the equivalent frequency function one may consider the simple passive network of Figure 3. The response in the frequency domain (vector frequency response) for this simple network is shown in Figure 4. Since equation 3 is nothing more than the frequency spectrum of the Heaviside step function, the output spectrum $G(\omega)$ of the network is simply the product of this expression and the vector frequency response. The response in the time domain (transient response) is obtained through application of the inverse Laplace transformation to the output spectrum to give

$$L^{-1}[G(\omega)]=\left[1-\epsilon^{-\frac{T}{RC}}\right] \tag{4}$$

The right member of this expression is recognized as nothing more than the transient response, shown in Figure 5, obtained through solution of the classical differential equation for the application of the step function to the input terminals of the network shown in Figure 3.

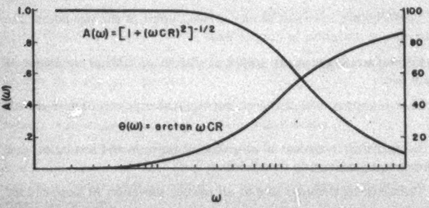

Figure 4. The response in the frequency domain (vector frequency response) for the resistance-capacitance passive network shown in Figure 3

CONCLUSION

The equivalence of the responses in the frequency and time domains for the simple network of Figure 3 illustrates further the suggestion that the spectrum of the Heaviside step function may be regarded as a standard frequency variation applicable to the study of transient behavior just as the sinusoid and cosinoid are standard time variations applicable to the study of steady-state behavior. Thus the transient and steady-state concepts of the behavior of electric and mechanical networks may be considered to be reciprocally related. Restated, the concepts of the transient and steady-state response are nothing more than alternative viewpoints of network behavior which are mutually exclusive, and this is the important point the student must grasp. The choice of viewpoint will depend upon whether one is interested in expressing network behavior in the time domain or the frequency domain.

The practical utility of each viewpoint may be readily appreciated by considering some of the problems encountered in the field of communication and television engineering. The communication engineer, who is interested primarily in selecting only one signal from among many signals in a frequency-sharing transmission system, is evidently interested in the response of his terminal devices as a function of frequency. Thus the behavior of the passive networks associated with the terminal devices in the frequency domain (vector frequency response) is of direct and immediate value.

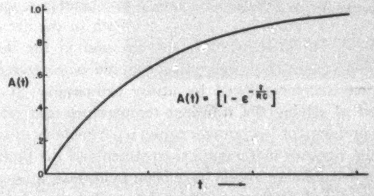

Figure 5. The response in the time domain of the resistance-capacitance passive network shown in Figure 3 which is obtained by the inverse Laplace transformation to the output spectrum to give $L^{-1}G(\omega)=\left[1-\epsilon^{-\frac{t}{RC}}\right]$

Equivalence of responses in the frequency and time domains (Figures 4 and 5) suggests that the spectrum of the Heaviside step function be regarded as standard frequency variation applicable to the study of transient behavior

The television engineer, on the other hand, who is interested primarily in the highest picture definition of which the transmission system is capable, is vitally concerned with the deformation of the video pulses corresponding to each picture element. Since deformation of these pulses represents a change in their shapes or wave forms, which are always expressed as functions of time, it is evident that network behavior in the time domain (transient response) is of more direct significance.

Although the foregoing example serves to illustrate a point, it should be recognized that the applicability of each viewpoint is not nearly as simple as it may appear since a desired steady-state and transient response characteristic for a given network cannot be chosen independently. This is a direct consequence of the reciprocity of the concepts discussed.

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2. Communication Engineering (book), W. L. Everitt. McGraw-Hill Book Company, Inc., New York, N. Y., 1937. Pages 8–19.

Temperature of Three-Conductor Cables

F. O. WOLLASTON
MEMBER AIEE

ALTHOUGH important problems in the field of cable engineering require the determination of transient temperatures of cables, the rather formidable mathematics involved in a rigorous solution discourages many engineers from attempting these calculations. Thus, comparatively few engineers are familiar with the methods of solving such problems. Since the ability to handle transient temperature calculations is necessary both in the determination of short-time overload ratings and in the design of oil-filled cable lines, this subject should be mastered by cable engineers employed by utility companies. A new method of solving the transient temperature and oil demand problems of 3-conductor cables is particularly stressed.

While rigorous mathematical treatments of the problem for single-conductor cables have been published, a rigorous solution for 3-conductor cables has not been obtained because there is no satisfactory mathematical formula for the thermal resistance of the insulation. It is therefore necessary to adopt the device of converting a 3-conductor cable into an equivalent single-conductor cable, after which the single-conductor solution can be applied. Earlier investigators have proposed that this be done by treating each core of a 3-conductor cable as a separate single-conductor cable in the calculations. This treatment will not give correct results unless the heat in each core flows outward uniformly in all directions from each conductor. The heat flow in the usual types of 3-conductor cables is considerably at variance with such a pattern.

Experimental measurements of insulation thermal resistance for various 3-conductor shielded cables of the solid type show that the heat flow is predominantly from the backs of the conductors. In belted cables with sector-shaped conductors, where the insulation between conductors is relatively thin, it is impossible for any appreciable amount of heat to flow into the insulation between conductors. Most of the heat must flow out from the backs of the conductors nearest the sheath. These facts lead to the conception that as far as heat flow is concerned, the three conductors and the insulation between them can be considered to act as a single conductor. The use of this concept enables the known mathematical solution of transient temperature problems of single-conductor cables to be readily applied to 3-conductor cables. Calculations for 3-conductor cables have been checked against experimental determinations of transient temperatures.

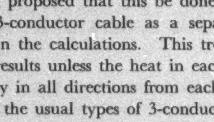

Figure 1. Equivalent single conductors for 3-conductor cables

Shaded areas delineate the equivalent single conductors
A—500,000-circular-mil type-H cable
B—450,000-circular-mil 69-kv oil-filled cable

The conversion of a 3-conductor cable into an equivalent single-conductor cable is handled in the following manner. The outside diameter and thickness of the lead sheath are not altered. This insures that the dissipation of heat through the sheath of the equivalent cable will take place in identically the same way as in the original cable. The diameter d of the equivalent single conductor is obtained by solving the equation $R_t=0.00522p \ln D/d$, in which all quantities except d are known. The symbol D is the inside diameter of the lead sheath; p is the unit thermal resistivity of the insulation and R_t is the total thermal resistance of the insulation. If the values of R_t and p are correct for the original cable, then the equivalent cable will have the correct ultimate temperature rise of copper above sheath. The periphery of the equivalent conductor may or may not coincide with the periphery of the original conductors (Figure 1).

By the use of rigorous mathematical methods the solution of the following problems of 3-conductor cables can be obtained:

1. Conductor temperature transient due to an abrupt variation in copper loss.
2. Sheath temperature transient due to an abrupt variation in copper loss.
3. Temperature transient at any desired point in the insulation due to an abrupt variation in copper loss.
4. Conductor temperature transient due to an abrupt variation in sheath loss.
5. Sheath temperature transient due to an abrupt variation in sheath loss.
6. Temperature transient at any desired point in the insulation due to an abrupt variation in sheath loss.
7. Transient oil demand due to an abrupt variation in copper loss.
8. Transient oil demand due to an abrupt variation in sheath loss.

The method is not suitable for calculating the temperature or oil-demand transients caused by an abrupt variation in dielectric loss in 3-conductor cables. The dielectric losses are generated in all portions of the insulation. Therefore their heat flow pattern cannot be predominantly from the backs of the conductors, as is necessary for the successful application of the equivalent single-conductor concept. The method will, however, handle the problems of transients due to dielectric losses in single-conductor cables, as well as the problems enumerated in the foregoing.

Digest of paper **49-268**, "Transient Temperature Phenomena of 3-Conductor Cables," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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A Double-Input Laboratory Oscilloscope

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THE ELECTRICAL engineering student engaged in a study of a-c theory is helped immensely in gaining a basic understanding of the interrelationships between the voltage and current quantities in a circuit when he is able to observe and study at least two of the quantities simultaneously. However, commercial apparatus which makes this possible, the oscillograph, the cathode-ray tube oscilloscope with "electronic-switches," and double-beam cathode-ray tube oscilloscopes, have been little used by the student himself because the problems of interconnections, time-base adjustments, synchronizing, calibration adjustments, and the like are beyond the abilities of the average student commencing his study of a-c circuits.

It is the purpose of this article to describe an instrument which is intended to enable the student to accomplish the above objectives with no more difficulty than would be involved in the use of an ordinary wattmeter. The student is not only able to observe two wave forms simultaneously, but is also able to measure the phase differences and instantaneous values of the two wave forms. All this is done in such a manner as to require no adjustments or calibrations on the part of the student.

The instrument is based upon a conventional single-beam cathode-ray oscilloscope but has incorporated special switching and time-base circuits and provision for input signals of the type encountered in the circuits and machine laboratory.

The special features of the instrument are obtained by the following design considerations:

1. A single-frequency, fixed time base is generated which corresponds to a 60-cycle period.
2. Stabilized signal-switching circuits (electronic switches) are used which require no balancing or gain adjustments.
3. Phase markers are generated from a stabilized oscillator which mark the time base according to 10-degree phase intervals and also act as a comparison standard for amplitude measurements of the input waveforms.

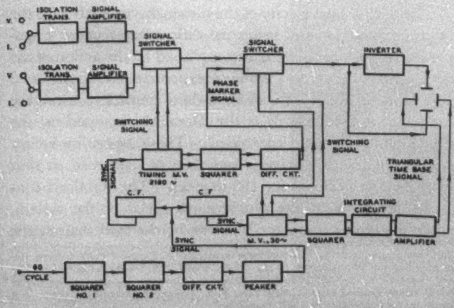

Figure 1. Block diagram, laboratory oscilloscope

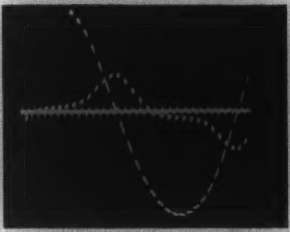

Figure 2. Voltage and exciting current, primary coil of a transformer

There are two signal inputs to the instrument. Each input may be set for either voltage or current, thereby enabling the simultaneous observation of two currents, two voltages, or a combination of the two. The following ranges are provided: for voltage, 0–50, 0–200, 0–500 peak volts; for current, 0–0.5, 0–2, 0–5 peak amperes. Measurement of larger currents are accomplished with a conventional current-transformer.

The input signals are combined in the first switcher, which is switched at 2,160 cycles per second. The output of the first switcher is combined with the phase marker signal in the second switcher, which is switched at 30 cycles per second. Both switchers utilize the stable properties of the cathode-follower to obtain switching without the need for gain or balancing adjustments. The output of the second switcher constitutes the vertical deflection signal of the cathode-ray tube.

There are two timing multivibrators (see Figure 1), both locked to a 60-cycle line through a synchronizing pulse. The first, the 2,160-cycle multivibrator, generates the switching signal for the first switcher and generates the phase marker signal. The second, the 30-cycle multivibrator, furnishes the switching signal for the second switcher and is also the basis for the generation of the time-base, which is produced as a triangular voltage and applied to the horizontal plates of the cathode-ray tube.

Figure 2 is a picture of the presentation of the instrument. The particular wave forms photographed are the voltage and exciting current of the primary coil of a transformer. The phase marker "pips" are being used to measure the peak value of the exciting current.

The fact that the instrument can be quickly inserted into a circuit with no need for adjustment, that it gives a fairly accurate indication of phase differences and instantaneous values of two wave forms opens up a vast number of possibilities for helping the student to understand the relationships between the quantities in an a-c circuit.

Digest of paper 49-277, "A Double-Input Oscilloscope for the Study of Laboratory A-C Circuits," recommended by the AIEE Committee of Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Not scheduled for publication in AIEE *Transactions*.

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Synchronized Air-Borne Camera System

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A method of taking aerial photographs with synchronized movie cameras has been developed at Northwestern University for the Navy. Films are exposed at the rate of 20 frames per second, and the cameras are synchronized to within ±0.002 second. The system includes: a plane-to-plane radio link for controlling equipment and relating data between two or more aircraft; a timing system for relating all data to an accurate time base; oscillograph recording for continuously checking the accuracy of the motor control system and for interpolating the data to a higher degree of accuracy if required; dial photography designed especially to obtain high illumination and satisfactory pictures of fast moving dials; film coding for marking the film of different cameras for matching.

AN AIR-BORNE SYSTEM for collecting photographic data by means of synchronized motion picture cameras has been developed for the Bureau of Aeronautics of the United States Navy for use at the Naval Air Test Center, Patuxent River, Md., by the Aerial Measurements Laboratory, Northwestern University. The usual requirements for air-borne equipment, namely those of light weight, minimum size, and in this instance operation from direct current at 28 volts, were imposed on the design of the system and the components to be described. Specifications for camera operation were that exposures should be at the rate of 20 frames per second and should occur simultaneously between different cameras to within ±0.002 second.

The fulfillment of the requirements led to the development of two new features of camera synchronization: displacement control obtained by synchronizing the 3,600-rpm drive motors by means of pulses from the 1,200-rpm shutters; and velocity control obtained without resorting to electrical differentiation.

Two types of cameras manufactured by Bell and Howell Company, each driven to give 20 frames per second, are used in the present system, although other cameras and other film speeds can be used. The larger cameras are 35-millimeter Eymos with 1/[illegible]-horsepower d-c motors substituted for the original spring drives. The smaller cameras are 16-millimeter GSAP's stripped of their original motors and driven by flexible shafts from separate drive units. Each drive unit is powered by a single motor and can drive two cameras. Extensive tests of the flexible shaft have demonstrated that synchronization of camera shutters can be maintained to the prescribed accuracy tolerance of the control system provided there is no motion of the flexible-shaft cable housings during operation.

MOTOR CONTROL

Since the speed of a series-wound d-c motor is proportional to the input voltage, a system has been developed in which the voltage applied to the motor is a function of the motor speed.

1. The angular velocity, ω_2, of the motor-driven load shaft is compared with a reference shaft operating at the desired velocity, ω_1, and the difference, $\omega_1 - \omega_2$, is used to cause a synchronizing voltage pulse.

2. The synchronizing voltage is applied to the motor whenever the load shaft varies from a given angular phase position.

3. A control is added which responds to changes in velocity to minimize the hunting inherent in the displacement type of control described here.

The load-driving unit in the synchronizing system consists of a series d-c motor, at one end of which there is attached a 2-speed centrifugal governor, and to the other end of which there is geared a 2-position rotary contactor (Figure 1) which is part of a displacement governor. The control unit of the synchronizing system is a multiunit master contactor, mounted separately and consisting of ganged 2-position rotary contactors (Figure 2). It is driven at the synchronous speed of the system and acts as the standard reference. Each load-driving unit synchronizes its operation to that of the standard reference through one of the rotary contactor units. Control is obtained through the use of the two governors, the displacement governor and the (centrifugal) velocity governor. The displacement governor provides positioning; the velocity governor reduces hunting.

Comparing the velocity of the motor-driven shaft with the reference velocity and using the difference to cause a synchronizing voltage pulse is accomplished by the action of the displacement governor, whose components are shown as *S* and *M* in Figure 3. *S* is one standard contactor unit of the master contactor and *M* is the contactor mounted on the motor which is being controlled. These 2-position rotary contactors are cam-driven, and they are adjusted so that each contact is closed for 180 degrees. The standard contactor is driven at the synchronous speed of the system, while the motor contactor is driven by the load shaft of the

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Full text of paper 50-43, "An Air-Borne Synchronized Motion Picture Camera Recording System," recommended by the AIEE Committee on Feedback-Control Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Not scheduled for publication in AIEE *Transactions*.

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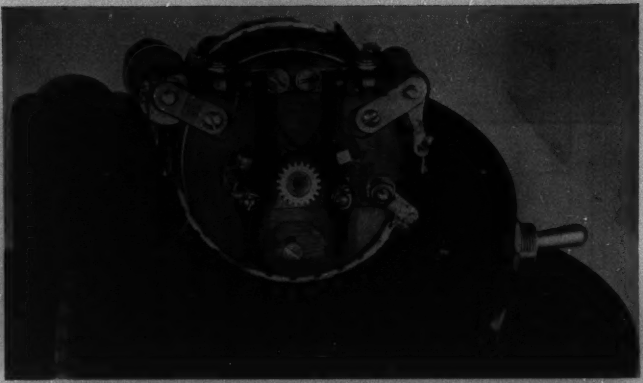


Figure 1. The 2-position rotary contactor which is geared to the series d-c motor of the load-driving unit of the synchronizing system (shown as M in Figure 3)

motor. As shown in Figure 3, the combined action of the contactors is to short-circuit the resistor *R* for a portion of each cycle through the simultaneous closure of corresponding contacts. The short-circuited voltage, equal to the impressed voltage *E*, is much higher than is necessary to maintain the torque requirements of the load at the synchronous speed of the system; while the open-circuited voltage, equal to $E-IR$, is much lower than is required. Hence, applied to the motor are voltage pulses of variable duration, of which the average value is just sufficient to develop the torque requirements of the load.

When voltage is first applied, the lower speed portion (*G*, Figure 3) of the centrifugal governor, short-circuiting the complete controlling system, rapidly brings the motor and contactor close to synchronous speed. As the speed reaches that of the standard contactor, controlling action commences. Both contactors are operating at the same speed, and the duration of pulse is varied with any change in phase position of the motor contactor with respect to the standard. The voltage pulses can vary in duration from 0 to 180 degrees, which corresponds to a variation of impressed average voltage between the limits of $(E-IR)$ and *E*. The average voltage is held at that required to lock the motor into synchronous speed.

The introduction of a permanent series resistance lowers the peak voltage and causes the pulse to widen to maintain the same average voltage required by the load. Since the effectiveness of the synchronizing will not be changed, an adjustable series resistance is used as a means of dynamically changing the pulse width and hence the angular phase position of the load shaft. This also provides a method of obtaining control over a wide range of loads by varying the voltage limits.

Although there are two phase positions which can furnish the same pulse duration, only one of them furnishes control. When the motor contacts close before the corresponding standard contacts, that is, the motor leads the standard, Figure 4*A*, a momentary loss of motor speed increases the pulse duration and therefore the average voltage, and a momentary gain of speed decreases the pulse duration. This gives the desired control. The contacts will not assume the lagging phase position, Figure 4*B*, because any displacement immediately causes a loss or gain of speed sufficient to cause the contacts to reach the leading position.

Applying the synchronizing voltage to the motor when the load shaft varies from a given angular phase position is accomplished by actuating the displacement governor contactor, *M*, directly by the load shaft. For a given load the motor contactor maintains an almost constant phase position with respect to the standard contactor; and since the motor contactor is mechanically coupled to the load shaft, the load assumes a definite angular phase position. When each load has the same phase relationship with its own standard contactor unit, synchronization between loads is obtained since all standard contactor units are driven by the same source (Figure 2).

With control of load position and load speed a function

Figure 2. The master contractor consists of ganged 2-position rotary contactors; it is driven at the synchronous speed of the system and acts as the standard reference (see contactor S in Figure 3)

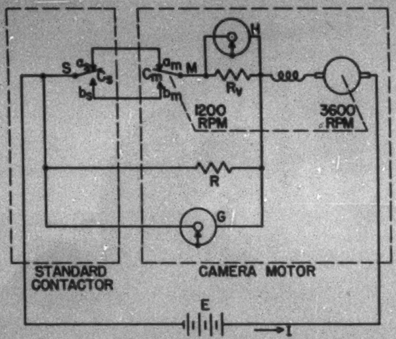


Figure 3. A synchronizing voltage pulse is obtained from the motor control circuit: S is one standard contactor unit of the master contactor, and M is the contactor of the motor which is to be controlled; G is the lower speed portion of the centrifugal governor, and H is the velocity governor

of the contactor action, both positioning and speed are independent of the rated motor speed, and so the motor may be geared up or down to the load shaft if desired. The relationship of motor speed to load speed is one of the factors which establishes the number of voltage pulses the motor receives per revolution and which, in turn, determines the effectiveness of control.

The average value of the voltage varies directly with the ratio of pulse width to the pulse period. Therefore, by increasing the number of pulses (which means decreasing their period) the control sensitivity is increased and less hunting should occur. However, increasing the number of contacts in order to increase the number of voltage pulses adds to the mechanical complexity of the contactor. A further practical limit which must be applied to a multisegment commutator is that the brush width must not exceed the segment insulator width.

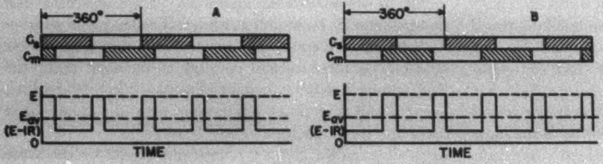


Figure 4. Graphical representation of the motor contactor action

(A) the motor leads the standard and stable operation occurs; (B) the motor lags the standard and unstable operation results. The contacts will not assume the lagging position because any displacement causes a change in speed sufficient to keep the contacts in a leading position

Adding a control to minimize hunting is accomplished through the use of the velocity governor (*H*, Figure 3). As was indicated previously, displacement control requires that some position error exist before a correcting effect will occur, and consequently, if applied alone, the motor hunts. This hunting, amounting to approximately 0.006 second is more than can be tolerated. To stabilize this condition a velocity control is provided by introducing in series with the contactor circuit the resistance R_v and the velocity governor contacts.

The Lee-type governor, *H*, consisting of a centrifugally operated high-frequency vibrating contact, is affixed to the shaft of the motor to be controlled. When it is connected into the motor circuit through suitable slip-rings and brushes and by-passed by a resistance, the current through the motor is reduced each time the governor contacts open. Controlling action occurs because an increase in velocity produces shorter closed periods of the contacts, and a decrease in velocity produces longer closed periods. The pulse shape (Figure 5) of the voltage applied to the motor is the result of the action of its two governors, and the shaft oscillations about a mean mechanical phase position are practically damped out. The successful controlling action of the velocity governor is related to the high frequency of the pulses produced by the vibrating contact. This frequency is determined by the natural period of the spring and moving contact.

Figure 6 is a block diagram of the complete system, in which the synchronizing control circuits are indicated by solid lines, the system control circuits by dash-dot lines, and the timing circuits by dashed lines.

In addition to the motor control equipment already described, some operation-control equipment was necessary to start and stop the entire camera system in a definite sequence from conveniently located stations and to insure that the failure of any part of the equipment to operate would manifest itself. The main operation-control unit contains the relays which switch on the power to the different parts of the equipment, control the sequence of operations, and prevent the running of the camera if some essential portion of the system is inoperative. The operation-control system is designed so that the operators only have to turn on the power switch, dial a number, and push buttons designated "ready," "start," and "catalogue-stop." The system is monitored by an operator at a central control station while the actual starting and stopping of the cameras are performed by an observer who is located at any strategic station in the ship.

AUXILIARY APPARATUS

Airplane-to-Airplane Radio Link. The operation-control equipment, located in the parent aircraft, also performs

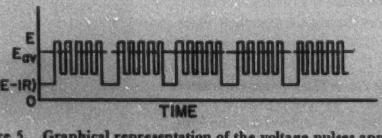
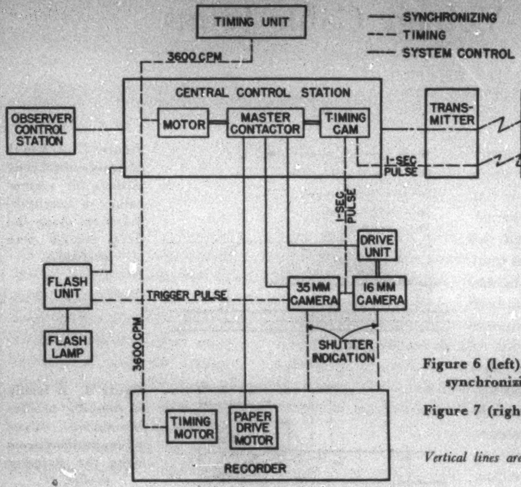


Figure 5. Graphical representation of the voltage pulses applied to the motor resulting from the action of the velocity and displacement governors



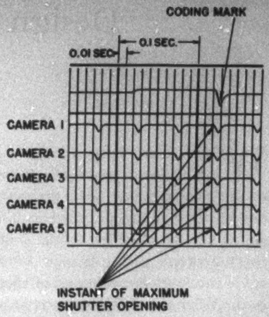


Figure 6 (left). Block diagram of the complete camera system showing synchronizing circuits, timing circuits, and system control circuits

Figure 7 (right). Sample oscillograph traces showing the occurrence of shutter openings for various cameras

Vertical lines are produced by a rotating slotted drum driven by the timing motor to provide the time scale

the ready, start, and catalogue-stop operations for cameras located in a remote aircraft through a frequency-modulated radio link. Control impulses which are picked up at the various sequencing relays in the parent unit modulate a transmitter. Demodulated signals in the remote aircraft duplicate the control sequence in a smaller version of the parent installation. The remote unit has its own time base, synchronizing and control elements, and recording equipment. In addition to the control functions, one-second timing marks are transmitted and appear on the records of both aircraft.

Timing System. The frequency standard of the system is a 60-cycle tuning fork which controls a vibrator power supply. The output of this timing unit is used to drive the master-contactor synchronous motor and an oscillograph synchronous timing motor. The master-contactor motor controls the speed of the camera motors and the repetition rate of a timing pulse. The oscillograph timing motor controls the time scale which appears on the record.

Oscillograph Recording. A means of checking camera performance is provided by using a 12-channel recording oscillograph. Figure 7 is a sample of the record obtained showing the occurrence of shutter openings. The instants of maximum shutter openings are indicated by trace deflections. One trace is used to record the coding marks which appear on all films. The vertical lines produced by a rotating slotted drum driven by the synchronous timing motor provide the time scale. Timing-line intervals of 0.01 second are spaced approximately 5/32 inch apart and experience has shown that interpolation to 0.001 second is possible. The speed of the motor driving the paper is controlled so that the recorder paper and camera film will be used at the same rate.

Dial Photography. Photography of fast-moving dials is somewhat of a problem for various reasons. Tremendous illumination is required to compensate for the relatively short exposure time of the camera. In the installation being discussed it is impossible with conventional lighting to obtain adequate illumination because of the geometry and small size of the dial locations. Although the open-shutter time is approximately 0.01 second, the dials may move an appreciable amount during this time, resulting in a blurred image. To overcome these difficulties, Edgerton-type high-speed flash lamps are employed. These lamps, small in size, with intense short-duration illumination, are triggered from a contact on the shutter of a single camera. When triggered, these lamps flash simultaneously and yield illumination for approximately 0.00004 second. Thus they not only permit clear photography by stopping dial motion, but they also provide extremely accurate synchronization of photographs so exposed.

Film Coding. Matching of corresponding frames of film from different cameras for correlation of data is achieved by film coding. One-second timing marks are placed simultaneously on each film and on the recorder paper, and catalogue marks indicate the end of such series of exposures. To produce a flash of short duration an inductive voltage pulse is utilized for firing small neon lamps mounted on each camera. These flashes expose the film directly through small holes drilled in the aperture plates and produce distinct dots near the edge of the film. The cataloguing marks are displaced slightly from the timing marks and appear as a series of dots, the number of which is equal to the identification number of the particular series of exposures.

As a result of the system described, the record obtained consists of the film from each camera and traces on oscillograph paper. The timing marks, which are recorded simultaneously on the films and oscillograph records in both aircraft, relate the information as functions of time.

Design of High-Voltage Cable Joints

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MEMBER AIEE

WHILE there exists a large volume of printed matter on all the aspects of high-voltage cables, the design of the related joints on a theoretically rigorous basis has not hitherto been published in a comprehensive manner. Joints can be classified as the homogeneous case and the heterogeneous case. In the former case the joint and cable insulants are assumed of identical material, whereas in the latter the conditions pertain where the cable insulant is of the usual graded construction and the joint insulant of some different material or dielectric constant.

The cable joint as such may be considered to be composed of three elemental parts—the ferrule or connector, Figure 1, which joins together electrically and mechanically the two cable ends; the tapering down of the cable insulant adjacent to the ferrule, called the "stepping" or the stepping profile, Figure 1, which forms the transitional bounding curve between the cable insulant diameter and the conductor diameter; and the stress control cone profile, Figure 2, which forms the bounding curve between the joint insulant diameter and the cable insulant diameter.

The long-time voltage breakdown strength of impregnated paper in cable form normal to the paper, and at atmospheric pressure, has been found to be 15 times greater than that in the longitudinal plane of the paper. Hence the longitudinal component of the electric field gradient (called the longitudinal stress) along the stress control cone profile and the stepping profile must be controlled with due regard to this 15:1 relationship. Under atmospheric transient surge voltages (impulse voltage breakdown strength) the same failing is exhibited so that from this point of view the longitudinal stress, particularly along the stepping treads, must be accommodated appropriately. The limiting value of the longitudinal stresses, which come into play when the electric field is disturbed, is that at which incipient deterioration of the insulating tapes along and within the stress control cone profile and along the stepping profile is amply prevented.

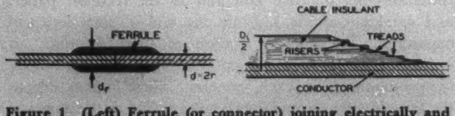

Figure 1 (Left) Ferrule (or connector) joining electrically and mechanically the conductors of the two cable ends; (right) the "stepping" of the cable insulant of one of the cable ends, in the joint adjacent to the ferrule

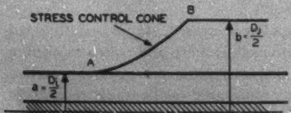

Figure 2. The stress control cone profile

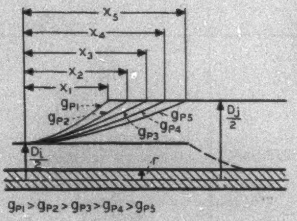

Figure 3. A family of stress control cone profiles for various values of longitudinal stress along the stress control cone profile, g_p

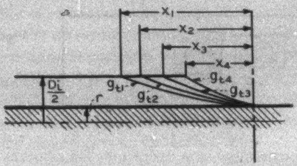

Figure 4. A family of stepping profiles for various values of longitudinal stress along the stepping profile, g_t

The longitudinal stress then becomes the criterion, and the corollary transpires that these transitional boundaries will be functions of the longitudinal stress along them. Formulas for the longitudinal stress along the stress control cone may be derived by resolving the 3-dimensional electric field. The equation for this stress is an exponential function of the potential drop, the conductor diameter, and the cable insulant diameter from which the *x* and *y* co-ordinates of the stress control cone may be computed. Hence a curve may be drawn to reveal the proper profile for the transitional boundary and some particular value of the related longitudinal stress. By this method a stress control cone may be determined having a constant longitudinal stress along its profile. For varying values of this stress a series of curves may be developed, as shown in Figure 3, which have a common origin to reveal the significance of the longitudinal stress along the stress control cone in determining the over-all length of the joint.

By similar reasoning formulas for the longitudinal stress along the stepping profile may be derived, and once again a family of exponential curves may be developed for varying values of this stress (Figure 4). By choosing suitable minimum and maximum values for the stress along the stepping profile the actual risers and treads of the stepping may be found such that a constant longitudinal stress obtains from the conductors up the stepping.

All the formulas are readily applicable to the practical design of cable joints and permit of a less cumbersome method of calculating the desired profiles than has been available up to now.

Digest of paper 49-267, "A Theoretical and Practical Approach to the Design of High-Voltage Cable Joints," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Air-Core Reactors as Fault Limiting Means on High Interrupting Capacity Controllers

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FELLOW AIEE

This article deals with the design and application of air-core reactors for motor branch circuits in conjunction with high interrupting capacity controllers. By selecting reactors capable of limiting a source of infinite power to 25,000 kva, much of the time-consuming calculations of system constants is eliminated. However, there are two factors which limit the range of application of such air-core reactors.

THE USE of air-core reactors as current-limiting means is very old and well established. They are used in large power networks for the protection of the generating equipment and the transmission system. Because of large currents in such networks, the reactors have very small inductances to avoid excessive voltage drops and are made of large conductors to keep losses within reasonable values. The electromagnetic forces, experienced during a fault, demand very rigid construction; consequently they often are embedded in concrete. If, however, reactors are installed in feeder or branch circuits where the normal currents are of much lower values, their inductances can be increased proportionately, limiting fault currents to lower values.

For many years it has been the general practice to install motor controllers with moderate interrupting capacity (ten times their rating) in branch circuits without regard to the available kilovolt-amperes at the point of installation. It was considered adequate to provide protection for these and other branch circuits with a backup circuit breaker. In the event of a fault, the controller opens before the circuit breaker but often fails to clear the circuit; thus it requires operation of the circuit breaker but not before considerable damage has been done. To overcome this, there recently has been an increase in the use of current-limiting fuses in conjunction with moderate interrupting capacity controllers. It is difficult to correlate such fuses and controllers so that the fuse clears the circuit on partial faults slightly above the interrupting capacity of the controller. This correlation is much easier when current-limiting fuses are used in conjunction with high interrupting capacity controllers. In either case one or more fuses must be replaced after the interruption of a fault.

When air-core reactors are designed to limit fault currents below the interrupting ability of moderate interrupting capacity controllers, the required inductances are so high that the reactors become too large and costly and the voltage drops too great. When the reactors are designed for use with high interrupting capacity controllers (50,000 kva), the required inductances are much less; this, combined with smaller currents in the motor branch circuits, results in reactors of surprisingly small size and weight.

In selecting circuit breakers for installation at various points in a power distribution system, it is customary to calculate, or in some way determine, the maximum available fault current at each point and to select circuit breakers having interrupting abilities in excess of these possible currents. Any increase in the available kilovolt-amperes necessitates a review of the system to determine the adequacy of the protection provided by existing circuit breakers.

Similar analysis usually is made prior to the selection of high interrupting capacity controllers in motor branch circuits although calculations rarely go beyond the last bank of transformers. Having estimated that the maximum available fault might be 20,000 kva, it is customary to install starters having interrupting capacities of 25,000 or 50,000 kva, depending upon the likelihood of increasing the available kilovolt-amperes at some future date. Frequently, however, the available kilovolt-amperes is increased beyond the interrupting capacity of the controller, necessitating a costly change.

By the introduction of adequate impedance in the branch circuit at the controller, the maximum fault can be limited to 25,000 kva. If, in addition, the controller itself has an interrupting capacity of 50,000 kva, adequate protection is provided in the circuit irrespective of any future increase in the available kilovolt-amperes of the system. If a particular feeder circuit supplies power to more than one motor, it might appear to be good practice to install one set of air-core reactors for the entire group of motors. Should additional motors be connected at some future time, new reactors probably would be required. By installing individual reactors for each motor, the reactors themselves are smaller and the installation is independent of future changes in feeder load. There are two other advantages to the use of individual reactors. The voltage drop is lower and excessive fault currents cannot flow between machines connected on a common feeder.

The design and application of air-core reactors for motor branch circuits in conjunction with high interrupting capacity controllers is dealt with in this article. By the selection of reactors which are capable of limiting a source of infinite power to 25,000 kva, much of the time-consuming calcula-

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Essential substance of paper 49-117, "The Use of Air-Core Reactors as Fault-Limiting Means on High Interrupting Capacity Controllers," recommended by the AIEE Industrial Control Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30-February 3, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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tion of system constants is eliminated. There are, however, two factors which limit the range of application of such air-core reactors. One is their increase in size and weight with increase in horsepower, while the other is the reduction in voltage at the motor during starting.

MOTOR CIRCUITS

When applying high interrupting capacity controllers to motor circuits, it is customary to assume infinite available kilovolt-amperes at the primary of the feeder transformer since the primary circuit impedance is usually low relative to that of the transformer itself and the motor lines. Assuming the transformer to have an impedance of six per cent, the maximum available kilovolt-amperes at its secondary terminals may be taken as its rated kilovolt-amperes divided by 0.06. The impedance of the transformer can be expressed as an equivalent secondary line reactance X_L.

$$\frac{E^2}{1{,}000X_L} = \text{maximum available kilovolt-amperes} \qquad (1)$$

where E is the line-to-line open-circuit secondary voltage.

Table I lists the available kilovolt-amperes at the transformer secondary and the equivalent line reactance for a series of 6-per-cent impedance transformers of different rated kilovolt-amperes having 2,300- and 4,600-volt secondaries. The last two columns list the additional reactance per line necessary to reduce the available kilovolt-amperes to 25,000. For example, the equivalent line reactance of a 4,000-kva 6-per-cent impedance transformer at 2,300 volts is 0.08 ohm; the reactance required to reduce infinite available kilovolt-amperes to 25,000 is 0.21 ohm, and the difference, 0.13 ohm, is the necessary additional reactance.

It is obvious that for transformers of lower rated kilovolt-amperes there is no need for air-core reactors as a fault-limiting means if controllers are used having interrupting abilities of 50,000 kva. The reactances of the lines themselves have been neglected, but if the lines are widely spaced and of considerable length they will reduce the available kilovolt-amperes at the motor. In applying air-core reactors, it would be a waste of power and equipment to install them (on a starter) at the end of a long line.

Figure 1 shows graphically the reactance necessary to reduce any available kilovolt-amperes to 25,000 at 2,300 volts. Referring to the ordinate for 200,000 available kilovolt-amperes, the amount of reactance required to reduce infinite available kilovolt-amperes to 200,000 is given by AB on the curve. This reactance (0.026 ohm) is only 14 per cent of that required (0.184 ohm) to reduce 200,000 available kilovolt-amperes to 25,000.

Table I. Equivalent Line Reactance for 6-Per-Cent Impedance Transformers, and Additional Reactance Necessary to Reduce Available Kilovolt-Amperes to 25,000

Transformer Rating, Kva, 6 Per Cent Impedance	Available Kva at Transformer Secondary	Equivalent Line Reactance in Ohms		Additional Reactance Per Line Necessary to Reduce Available Kva to 25,000	
		2,300 Volts	4,600 Volts	2,300 Volts	4,600 Volts
1,000	16,600	0.32	1.28	0	0
1,500	25,000	0.21	0.84	0	0
2,000	33,000	0.16	0.64	0.05	0.2
3,000	50,000	0.105	0.42	0.105	0.4
4,000	66,000	0.08	0.32	0.13	0.52
5,000	83,000	0.064	0.25	0.15	0.60
6,000	100,000	0.053	0.21	0.16	0.64
7,000	116,000	0.045	0.18	0.165	0.66
8,000	133,000	0.04	0.16	0.17	0.68
9,000	150,000	0.035	0.14	0.175	0.70
10,000	166,000	0.032	0.13	0.178	0.71
12,000	200,000	0.026	0.105	0.184	0.74

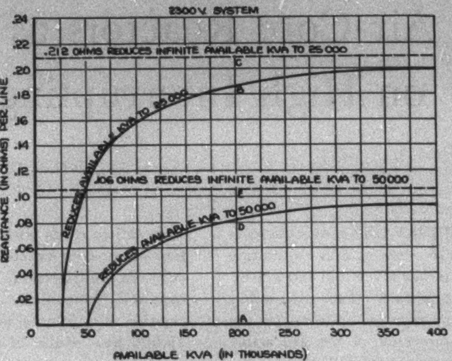

Figure 1. Graphical representation of the reactance necessary to reduce any available kilovolt-amperes to 25,000 at 2,300 volts

All the calculations so far have been based on steady-state fault currents. Actually, the controller is called upon to interrupt currents of somewhat higher values because of the existence of transient d-c components. Under certain circuit conditions if a short circuit is applied at the instant $E=0$, the current wave is displaced by an amount equal to the peak value of the steady-state wave. It can be shown easily that the *total* rms value of a completely displaced sine wave is equal to $\sqrt{3}$ times the rms value of the a-c wave alone. Actually the d-c component decays exponentially and disappears within a few cycles. If interruption occurs within the first half cycle (60 cycles per second), the total rms current interrupted might be as high as 1.5 times the rms value of the a-c component.

In applying current-limiting high interrupting capacity fuses to motor feeder circuits, it is customary to multiply the available steady-state fault currents by 1.6 to obtain the total rms current that one of the three fuses may be called upon to interrupt during the first quarter cycle of a fault. In selecting circuit breakers for circuits having known available steady-state fault currents, the "operating time" of the circuit breaker is important since the delay in opening is used along with the "decrement" characteristics of the circuit in determining the total rms current to be interrupted.

High interrupting capacity controllers, which are not latched in, start to part their contacts within a cycle of the instant of fault. Tests show the presence of total rms currents as high as 1.5 times the a-c component at the instant of interruption. Thus the interrupting capacity of the controller should be at least 50 per cent above the maximum available steady-state fault kilovolt-amperes. The present top rating of standard high interrupting capacity controllers is 50,000 kva at 2,300 and 4,600 volts, based on the average of the phase currents including the d-c components. Therefore, it was decided to use air-core reactors which would limit infinite available kilovolt-amperes to 25,000 steady state, thereby providing an additional factor of safety over that inherent in the controller.

DESIGN AND APPLICATION OF REACTORS

From an economic point of view, it is desirable to use a minimum number of reactors for a given range in motor sizes. Figure 1 shows only a small difference in the reactance required to limit 100,000 or more kilovolt-amperes to 25,000 and that required to limit infinite available kilovolt-amperes to the same value. By considering only infinite available kilovolt-amperes, the required number of reactors is greatly reduced, and each installation is independent of the system constants and future changes in the available kilovolt-amperes. On actual systems having finite available kilovolt-amperes, the use of such reactors will reduce the available kilovolt-amperes to slightly less than 25,000.

The reactance required to reduce any available kilovolt-amperes from one value to another is proportional to the square of the voltage, and the inductance corresponding to any reactance varies inversely as the frequency of the system. Assuming only infinite available kilovolt-amperes to be reduced to 25,000, 0.21 ohm is required at 2,300 volts and 0.84 ohm at 4,600 volts. The corresponding inductances for 60-cycle systems are 0.56 and 2.24 millihenrys while for 25-cycle systems the corresponding inductances are 1.34 and 5.36 millihenrys.

Before a reactor can be designed for a motor circuit of given horsepower, it is necessary to decide upon an acceptable power loss at full load. Assuming a power loss in the resistance of the coil of 100 watts per coil at 25 degrees centigrade, the resistance of the coil is determined and consequently the cross section of the copper. Such an assumption neglects eddy-current losses in the coil and the starter enclosure and does not specify any limit of temperature rise. These can best be determined by test.

Assuming, for the moment, a power loss in the resistance of the coil of 100 watts per coil, the empirical formula

$$L=\frac{aN^2}{238\times10^6}\text{ henrys} \qquad (2)$$

can be used in designing air-core reactors. N is the number of turns and a is the radius of the mean turn in inches. This formula is quite accurate where $a=1.5b$ and where the coil has approximately a square cross section of dimension b. Table II lists the dimensions of a series of air-core reactors for 2,300-volt 60-cycle motors varying in size from 200 to 1,500 horsepower.

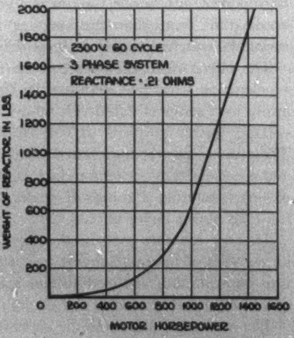

Figure 2. Variation of reactor weight with horsepower

The gradient of the curve is low up to 600 horsepower which suggests limiting reactors to that value

Table II. Variation in Reactor Size With Horsepower (0.56 Millihenry)

Maximum Horsepower	Turns	Dimensions (Inches): Inside Diameter	Dimensions (Inches): Outside Diameter	Dimensions (Inches): Width	Size of Copper	Resistance in Ohms at 25 Degrees Centigrade	Weight in Pounds
200	66	$3\tfrac{3}{4}$	$7\tfrac{1}{2}$	2	#5 Square	0.0243	$12\tfrac{1}{4}$
400	54	$5\tfrac{3}{4}$	$12\tfrac{3}{8}$	3	$\tfrac{3}{32}\times1\tfrac{1}{4}$	0.0087	$56\tfrac{1}{2}$
600	54	$5\tfrac{3}{4}$	14	4	$\tfrac{1}{8}\times1\tfrac{3}{4}$	0.0050	114
1,000	38	12	$24\tfrac{3}{4}$	$6\tfrac{1}{4}$	$\tfrac{5}{16}\times2\tfrac{7}{8}$	0.00164	625
1,500	40	14	32	$11\tfrac{1}{2}$	$\tfrac{7}{16}\times5\tfrac{1}{2}$	0.0007	2240

The strap-wound coils in Table II are 2-layer coils with suitable insulation between layers. It will be noted how rapidly the dimensions of the reactors increase with horsepower and how small they are for motors up to 600 horsepower. For fixed power losses in the resistance, the resistance of the coils must vary inversely as the square of the horsepower. As the copper cross section is increased, the radius of the mean turn increases, and consequently the weight of the reactor increases faster than the square of the horsepower. Figure 2 shows graphically how the reactor weight varies with horsepower. It will be noted that the average gradient of this curve is quite low up to 600 horsepower and that thereafter it increases rapidly. This suggests placing an upper limit of about 600 horsepower on the application of air-core reactors on 2,300-volt 60-cycle systems. There is, however, another and more important limitation to the application of air-core reactors with motor controllers.

If reactors are designed for various horsepowers at other voltages and frequencies, the same general results will be obtained. For 25-cycle systems, the inductances must be increased by the ratio 60/25 to obtain the same reactances; consequently the reactor size and weight will become quite large at about 300 horsepower. For 4,600-volt 60-cycle systems, the reactors will have four times the inductances for 2,300-volt systems. For the same reactor dimensions, the reactance and resistance remain in the same ratio; consequently, for the same power loss, the reactors again will become large at about 600 horsepower. Similarly, 4,600-volt 25-cycle reactors will be limited to about 300 horsepower. For the 4,600-volt reactors the number of turns is approximately twice that for 2,300-volt reactors, giving a poorer space factor. This explains why the 4,600-volt reactors in Table III have a slightly lower maximum rating than the corresponding 2,300-volt reactors at the same frequency.

Table III lists 11 reactors having weights as high as 160 pounds which may be applied to a wide range of motor sizes, a range which statistically represents more than 90 per cent of the total applications in this field.

All of the reactors in Table III are single-layer strap-wound coils. They have been tested thermally giving the results listed. All losses are given in watts at the operating temperature corresponding to the maximum horsepower tion of system constants is eliminated. There are, however, two factors which limit the range of application of such air-core reactors. One is their increase in size and weight with increase in horsepower, while the other is the reduction in voltage at the motor during starting.

MOTOR CIRCUITS

When applying high interrupting capacity controllers to motor circuits, it is customary to assume infinite available kilovolt-amperes at the primary of the feeder transformer since the primary circuit impedance is usually low relative to that of the transformer itself and the motor lines. Assuming the transformer to have an impedance of six per cent, the maximum available kilovolt-amperes at its secondary terminals may be taken as its rated kilovolt-amperes divided by 0.06. The impedance of the transformer can be expressed as an equivalent secondary line reactance X_L.

$$\frac{E^2}{1{,}000X_L} = \text{maximum available kilovolt-amperes} \qquad (1)$$

where E is the line-to-line open-circuit secondary voltage.

Table I lists the available kilovolt-amperes at the transformer secondary and the equivalent line reactance for a series of 6-per-cent impedance transformers of different rated kilovolt-amperes having 2,300- and 4,600-volt secondaries. The last two columns list the additional reactance per line necessary to reduce the available kilovolt-amperes to 25,000. For example, the equivalent line reactance of a 4,000-kva 6-per-cent impedance transformer at 2,300 volts is 0.08 ohm; the reactance required to reduce infinite available kilovolt-amperes to 25,000 is 0.21 ohm, and the difference, 0.13 ohm, is the necessary additional reactance.

It is obvious that for transformers of lower rated kilovolt-amperes there is no need for air-core reactors as a fault-limiting means if controllers are used having interrupting abilities of 50,000 kva. The reactances of the lines themselves have been neglected, but if the lines are widely spaced and of considerable length they will reduce the available kilovolt-amperes at the motor. In applying air-core reactors, it would be a waste of power and equipment to install them (on a starter) at the end of a long line.

Figure 1 shows graphically the reactance necessary to reduce any available kilovolt-amperes to 25,000 at 2,300 volts. Referring to the ordinate for 200,000 available kilovolt-amperes, the amount of reactance required to reduce infinite available kilovolt-amperes to 200,000 is given by *AB* on the curve. This reactance (0.026 ohm) is only 14 per cent of that required (0.184 ohm) to reduce 200,000 available kilovolt-amperes to 25,000.

Table I. Equivalent Line Reactance for 6-Per-Cent Impedance Transformers, and Additional Reactance Necessary to Reduce Available Kilovolt-Amperes to 25,000

Transformer Rating, Kva, 6 Per Cent Impedance	Available Kva at Transformer Secondary	Equivalent Line Reactance in Ohms		Additional Reactance Per Line Necessary to Reduce Available Kva to 25,000	
		2,300 Volts	4,600 Volts	2,300 Volts	4,600 Volts
1,000	16,600	0.32	1.28	0	0
1,500	25,000	0.21	0.84	0	0
2,000	33,000	0.16	0.64	0.05	0.2
3,000	50,000	0.105	0.42	0.105	0.4
4,000	66,000	0.08	0.32	0.13	0.52
5,000	83,000	0.064	0.25	0.15	0.60
6,000	100,000	0.053	0.21	0.16	0.64
7,000	116,000	0.045	0.18	0.165	0.66
8,000	133,000	0.04	0.16	0.17	0.68
9,000	150,000	0.035	0.14	0.175	0.70
10,000	166,000	0.032	0.13	0.178	0.71
12,000	200,000	0.026	0.105	0.184	0.74

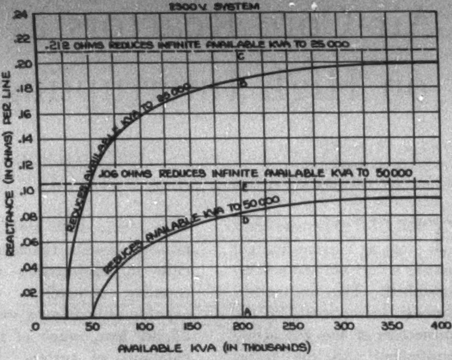

Figure 1. Graphical representation of the reactance necessary to reduce any available kilovolt-amperes to 25,000 at 2,300 volts

All the calculations so far have been based on steady-state fault currents. Actually, the controller is called upon to interrupt currents of somewhat higher values because of the existence of transient d-c components. Under certain circuit conditions if a short circuit is applied at the instant $E=0$, the current wave is displaced by an amount equal to the peak value of the steady-state wave. It can be shown easily that the *total* rms value of a completely displaced sine wave is equal to $\sqrt{3}$ times the rms value of the a-c wave alone. Actually the d-c component decays exponentially and disappears within a few cycles. If interruption occurs within the first half cycle (60 cycles per second), the total rms current interrupted might be as high as 1.5 times the rms value of the a-c component.

In applying current-limiting high interrupting capacity fuses to motor feeder circuits, it is customary to multiply the available steady-state fault currents by 1.6 to obtain the total rms current that one of the three fuses may be called upon to interrupt during the first quarter cycle of a fault. In selecting circuit breakers for circuits having known available steady-state fault currents, the "operating time" of the circuit breaker is important since the delay in opening is used along with the "decrement" characteristics of the circuit in determining the total rms current to be interrupted.

High interrupting capacity controllers, which are not latched in, start to part their contacts within a cycle of the instant of fault. Tests show the presence of total rms currents as high as 1.5 times the a-c component at the instant of interruption. Thus the interrupting capacity of the controller should be at least 50 per cent above the maximum available steady-state fault kilovolt-amperes. The present top rating of standard high interrupting capacity controllers is 50,000 kva at 2,300 and 4,600 volts, based on the average of the phase currents including the d-c components. Therefore, it was decided to use air-core reactors which would limit infinite available kilovolt-amperes to 25,000 steady state, thereby providing an additional factor of safety over that inherent in the controller.

DESIGN AND APPLICATION OF REACTORS

From an economic point of view, it is desirable to use a minimum number of reactors for a given range in motor sizes. Figure 1 shows only a small difference in the reactance required to limit 100,000 or more kilovolt-amperes to 25,000 and that required to limit infinite available kilovolt-amperes to the same value. By considering only infinite available kilovolt-amperes, the required number of reactors is greatly reduced, and each installation is independent of the system constants and future changes in the available kilovolt-amperes. On actual systems having finite available kilovolt-amperes, the use of such reactors will reduce the available kilovolt-amperes to slightly less than 25,000.

The reactance required to reduce any available kilovolt-amperes from one value to another is proportional to the square of the voltage, and the inductance corresponding to any reactance varies inversely as the frequency of the system. Assuming only infinite available kilovolt-amperes to be reduced to 25,000, 0.21 ohm is required at 2,300 volts and 0.84 ohm at 4,600 volts. The corresponding inductances for 60-cycle systems are 0.56 and 2.24 millihenrys while for 25-cycle systems the corresponding inductances are 1.34 and 5.36 millihenrys.

Before a reactor can be designed for a motor circuit of given horsepower, it is necessary to decide upon an acceptable power loss at full load. Assuming a power loss in the resistance of the coil of 100 watts per coil at 25 degrees centigrade, the resistance of the coil is determined and consequently the cross section of the copper. Such an assumption neglects eddy-current losses in the coil and the starter enclosure and does not specify any limit of temperature rise. These can best be determined by test.

Assuming, for the moment, a power loss in the resistance of the coil of 100 watts per coil, the empirical formula

$$L=\frac{aN^2}{238\times10^6}\text{ henrys} \tag{2}$$

can be used in designing air-core reactors. N is the number of turns and a is the radius of the mean turn in inches. This formula is quite accurate where $a=1.5b$ and where the coil has approximately a square cross section of dimension b. Table II lists the dimensions of a series of air-core reactors for 2,300-volt 60-cycle motors varying in size from 200 to 1,500 horsepower.

Table II. Variation in Reactor Size With Horsepower (0.56 Millihenry)

Maximum Horsepower	Turns	Dimensions (Inches) Inside Diameter	Outside Diameter	Width	Size of Copper	Resistance in Ohms at 25 Degrees Centigrade	Weight in Pounds
200	66	$3\frac{3}{4}$	$7\frac{1}{2}$	2	#5 Square	0.0243	$12\frac{1}{4}$
400	54	$5\frac{3}{4}$	$12\frac{3}{8}$	3	$\frac{3}{32}\times1\frac{1}{4}$	0.0087	$56\frac{1}{2}$
600	54	$5\frac{3}{4}$	14	4	$\frac{1}{8}\times1\frac{3}{4}$	0.0050	114
1,000	38	12	$24\frac{3}{4}$	$6\frac{1}{4}$	$\frac{5}{16}\times2\frac{7}{8}$	0.00164	625
1,500	40	14	32	$11\frac{1}{2}$	$\frac{7}{16}\times5\frac{1}{2}$	0.0007	2240

The strap-wound coils in Table II are 2-layer coils with suitable insulation between layers. It will be noted how rapidly the dimensions of the reactors increase with horsepower and how small they are for motors up to 600 horsepower. For fixed power losses in the resistance, the resistance of the coils must vary inversely as the square of the horsepower. As the copper cross section is increased, the radius of the mean turn increases, and consequently the weight of the reactor increases faster than the square of the horsepower. Figure 2 shows graphically how the reactor weight varies with horsepower. It will be noted that the average gradient of this curve is quite low up to 600 horsepower and that thereafter it increases rapidly. This suggests placing an upper limit of about 600 horsepower on the application of air-core reactors on 2,300-volt 60-cycle systems. There is, however, another and more important limitation to the application of air-core reactors with motor controllers.

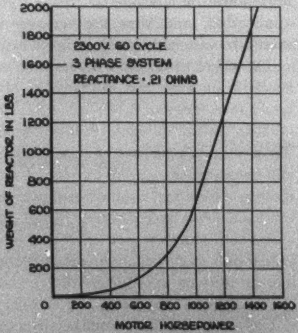

Figure 2. Variation of reactor weight with horsepower

The gradient of the curve is low up to 600 horsepower which suggests limiting reactors to that value

If reactors are designed for various horsepowers at other voltages and frequencies, the same general results will be obtained. For 25-cycle systems, the inductances must be increased by the ratio 60/25 to obtain the same reactances; consequently the reactor size and weight will become quite large at about 300 horsepower. For 4,600-volt 60-cycle systems, the reactors will have four times the inductances for 2,300-volt systems. For the same reactor dimensions, the reactance and resistance remain in the same ratio; consequently, for the same power loss, the reactors again will become large at about 600 horsepower. Similarly, 4,600-volt 25-cycle reactors will be limited to about 300 horsepower. For the 4,600-volt reactors the number of turns is approximately twice that for 2,300-volt reactors, giving a poorer space factor. This explains why the 4,600-volt reactors in Table III have a slightly lower maximum rating than the corresponding 2,300-volt reactors at the same frequency.

Table III lists 11 reactors having weights as high as 160 pounds which may be applied to a wide range of motor sizes, a range which statistically represents more than 90 per cent of the total applications in this field.

All of the reactors in Table III are single-layer strap-wound coils. They have been tested thermally giving the results listed. All losses are given in watts at the operating temperature corresponding to the maximum horsepower

Table III. Application of Air-Core Reactors

Reactor	Maximum Horsepower	Volts	Frequency in Cycles Per Second	Reactance in Ohms	Weight Per Coil in Pounds	Temperature Rise and Losses at Maximum Horsepower With Coils Mounted in Enclosure				
						Temperature Rise in Degrees Centigrade	Power Loss Per Coil	Eddy Current Loss Per Coil	Total Watts Per Coil	Total Watts Per Horsepower
1	200	2,300	60	0.21	26	59	49	56	105	1.57
2	300	2,300	60	0.21	43	69	76	101	177	1.77
3	400	2,300	60	0.21	69	65	95	152	247	1.85
4	600	2,300	60	0.21	158	65	121	339	460	2.30
5	300	4,600	60	0.84	58	64	75	158	233	2.33
6	400	4,600	60	0.84	89	75	95	257	352	2.63
7	500	4,600	60	0.84	160	66	95	380	475	2.85
8	200	2,300	25	0.21	44	60	77	53	130	1.95
9	300	2,300	25	0.21	73	78	133	119	252	2.52
10	350	2,300	25	0.21	117	66	118	140	258	2.21
11	300	4,600	25	0.84	97	62	126	121	247	2.47

Table IV. Effect of Air-Core Reactors on Motor Voltage and Torque 2,300-Volt 60-Cycle Systems, 0.21-Ohm Reactance Per Line

Maximum Horsepower	Full-Load Conditions				Starting Conditions					
	Current in Amperes	Motor Volts in Per Cent Line Volts	Motor Torque in Per Cent Full Voltage Torque	Reduction in Per Cent Power Factor	Inrush Currents		Motor Volts in Per Cent Line Volts		Motor Torque in Per Cent Full-Voltage Torque	
					7×Full-Load Current	10×Full-Load Current	7×Full-Load Current	10×Full-Load Current	7×Full-Load Current	10×Full-Load Current
200	50	99.5	99	0.3	333	465	95.1	93.0	90.5	86.4
400	100	99	98	0.6	635	868	90.6	86.9	82.0	75.3
600	150	98.9	97.7	1.0	905	1,220	86.5	81.2	74.4	66.1
1,000	250	97.9	95.8	1.8	1,387	1,810	79.4	72.5	63.0	52.5
1,500	375	96.7	93.2	3.0	1,873	2,390	71.7	63.3	51.2	40.1

ratings. The eddy-current losses include those within the coil and those in the enclosure and coil mounting. Nonmagnetic stainless-steel mountings reduce these losses.

It will also be noted that the temperature rise of the coil is well below recognized standards for class *B* insulation. The total power loss per horsepower for all three coils mounted in the enclosure is shown in the last column of the table and is relatively small, less than 0.4 per cent in the worst case. The temperature rise of the air within the enclosure does not exceed 20 degrees centigrade.

The insulation between turns is impregnated glass tape 0.020 inch in thickness. On test this insulation breaks down at about 7,000 rms alternating voltage.

It is easy to calculate the effect of the air-core reactors on motor voltage and torque during starting and running. The result of such calculations are given in Table IV for the five reactors and corresponding motor sizes of Table II. The motors are assumed to have full-voltage locked-rotor currents of seven and ten times full-load current.

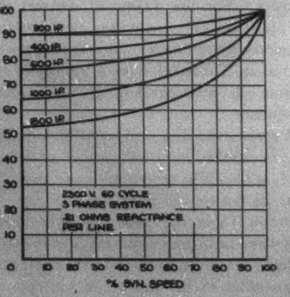

Figure 3. The effect of air-core reactors on motor torque during acceleration from rest for a series of 2,300-volt motors

In making the foregoing calculations, the standstill power factor of the motors having an inrush of seven times full-load current was assumed to be 0.35, and for motors having an inrush of ten times full-load current to be 0.30. A full-load power factor of 0.85 was assumed for all motors. Table IV shows the small change in per cent power factor caused by the air-core reactors at full load.

For a given series of reactors having a constant inductance, the voltage drop across the reactors is proportional to the horsepower of the motor. Obviously, there will be a practical upper limit to the motor size with which the reactors can be used, and this will be decided by the reduction in motor torque that can be tolerated during starting. As in the case of the reactor size limitation, it appears that 600 horsepower on 60-cycle systems is a good practical limit of application, and that the starting torque requirements should be watched closely on large drives.

The effect of air-core reactors on motor torque during acceleration from rest is shown in Figure 3. The curves apply to a series of 2,300-volt 60-cycle motors having full voltage inrush currents of 6.65 times full-load current. These curves were determined from typical speed-torque and speed-current curves for class *A* squirrel cage induction motors, assuming a standstill power factor of 0.35 and a full-load power factor of 0.85.

Air-core reactors used in this way, particularly on the larger sizes of motors, convert an "across-the-line" starter into an automatic reduced-voltage starter without the use of an additional contactor and transfer relay.

The method of mounting the air-core reactors in the controller enclosure is shown in Figure 4. The reasons for selecting such an arrangement of the coils are

1. To reduce the mutual inductance between the coils and assure a reactance per line independent of phase sequence.
2. To provide individual and uniform mounting.
3. To provide simple and rigid assembly.

With three coils mounted as shown in Figure 4, the electromagnetic forces between them produce torques about their perpendicular diameters, the greatest being that on the center coil marked *2*. For coils of fixed dimensions and fixed spacing, the force between them is proportional to the square of the ampere-turns or proportional to LI^2 where L is the self-inductance of each coil. For the same fault kilovolt-amperes, the quantity LI^2 is constant for both 2,300- and 4,600-volt systems at the same frequency since the inductances are proportional to the square of the voltage and the fault current is inversely proportional to the voltage. The inductances also vary inversely with system frequency while the fault currents are independent of the frequency; hence the electromagnetic forces on reactors used on 25-cycle systems will be 2.4 times the corresponding forces on 60-cycle systems.

Three reactors were arranged for test as shown in Figure 4, reactors *1* and *3* being rigidly fixed while the center reactor *2* was carefully pivoted about its vertical diameter. Current was led in and out of the center reactor by immersing the terminals in mercury-filled cups. An accurately calibrated spring was used in determining the torque required to return the reactor to its normal position when various values of 3-phase currents were passed through the three reactors. The measured torques were proportional to the square of the currents as expected, and by extrapolation the torque was estimated to be 75 pounds-feet at 6,250 amperes, the current corresponding to 25,000 kva at 2,300 volts. If the current were reversed in reactor *3* the torque was negligibly small as expected.

The particular reactors used in the test were 200-horsepower 2,300-volt 60-cycle reactors. Consequently, the torque for 25-cycle coils would be about 180 pounds-feet. These torques are the mean values, the peak being twice as great or 150 and 360 pounds-feet, respectively. At the instant of fault, the d-c components give initial total rms currents somewhat in excess of the steady-state currents. Allowing an additional factor of two for the effect of the d-c components, the torques became 300 and 720 pounds-feet, respectively. Unbalanced faults may increase these forces up to 50 per cent, but even then the torques do not present any mounting difficulties.

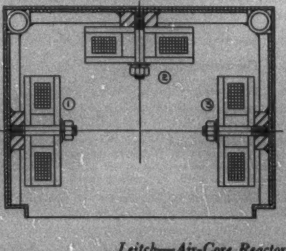

Figure 4. Air-core reactors are mounted in the controller enclosure so that mutual inductance between coils is reduced

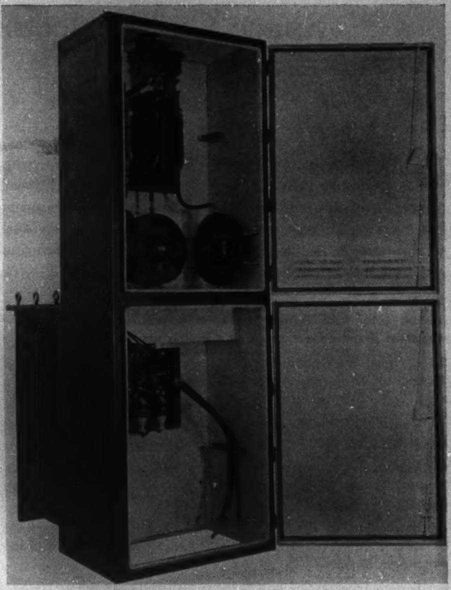

Figure 5. Air-core reactors on a 300-horsepower 4,600-volt oil-immersed across-the-line starter

The lower cabinet contains the overload protective panel and may enclose the field switching equipment in the case of a synchronous motor

Figure 5 is an illustration of an actual controller with air-core reactors mounted as described. The lower front cabinet contains the overload protective panel and also may enclose the field switching equipment in the case of a synchronous motor or the secondary contactors in the case of a wound rotor induction motor.

Short-time current ratings of conductors are expressed in amperes for one-quarter second, one-half second, or any other short-time interval. The short-time current ratings of the reactors and any other components of the controller must be in excess of the maximum anticipated fault currents for the time the controller takes to interrupt the circuit. The smallest of the 11 reactors, in Table III, is wound with 0.020-inch by 3-inch strap and has a one-quarter second rating of 20,000 amperes. This is considerably in excess of that required since the interrupting time of the controller is of the order of 0.05 second.

Following the same procedure as in the case of high-voltage systems, it was necessary to choose a limit for the fault current. If 10,000 steady-state amperes is chosen, and similar limitations in weight and starting torque are accepted, it appears that the range of application would be 100 horsepower at 220 volts, and 200 horsepower at 440 and 550 volts on 60-cycle systems. The 10,000-ampere limitation demands the use of controllers having rated interrupting capacities of 15,000 amperes or better including the d-c components.

Space Code Selector Supervisory System

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DURING the past 20 years, there have been numerous supervisory systems using various designs and basic principles of transmitting signals such as tone, counting chain codes, or sequence chain codes. Any supervisory system should fulfill the following essential operating requirements:

1. Transmit control circuit selection code and check this transmission before the control operation is performed. Prevent the operation if the correct checking signal is not received.
2. Be suitable for operation over any commonly available type of channel for use in controlling a number of outlying stations from a single control station.
3. Components should harmonize with other switchboard devices and thus be suitable for building into standard switchboards.
4. Equipment should be easy to expand to take care of future growth. Be simple, easy to install, maintain, test, and operate. Be rapid, have uniform speed of operation for all points.
5. Be available for either 48-volt or 125-volt d-c operation and have the same standard range of battery voltage as the remainder of the switchgear devices.
6. Include provision for telemetering and telephone communication.

The space code selector supervisory system meets these requirements. It uses a signal resembling the telegraph code which is transmitted and received by circuits composed of telephone-type relays. Instead of long and short impulses, the space code system uses impulses of the same length, but varies the time between the impulses to establish the various codes.

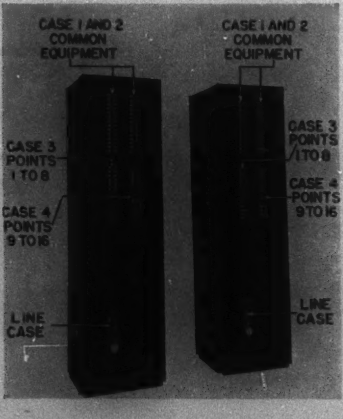

Figure 1. Rear view of supervisory equipment—control station on right, outlying station on left

Using eight impulses and varying the spaces between impulses, 128 code selections are obtained. After the selection of a point is complete, a code of four impulses is used to perform the control operation or transmit an indication. The system will lock out unless exactly eight impulses are sent and received for selection of a point and unless exactly four impulses are sent and received for the control and indication. The single-polarity impulse permits use on any type of channel which will carry signal intelligence such as single-polarity direct current, unmodulated carrier, single audio tone, or microwave.

The space code selector supervisory system consists of control station equipment which is illustrated in Figure 1. The two "common" relay cases (1 and 2) contain the supervisory relays required to transmit and receive codes for any system up to 128 points. The "point" case (3) contains relays for each eight points. The "line" case contains equipment required to adapt the supervisory system to the particular channel involved.

The relay cases are semiflush mounted, drawout switchboard type. Removable plugs permit inspection or entire removal from the board.

As the "common" relay cases (1 and 2) always contain the necessary code transmitting and receiving relays for 128 points, additional points can be added in groups of eight by simply adding another "point" case. Any system can be changed from operation over one type of channel to another by simply substituting the proper "line" case.

The space code selector supervisory system meets all the essential operating requirements previously outlined. In the design of the equipment special emphasis on providing maximum flexibility results in the following:

Telemetering equipment, suitable to the type of channel used, can be connected by supervisory selection to give intermittent readings over the supervisory channel. Torque balance telemeters are used for direct metallic wire channels, and impulse- or frequency-type telemeters are used for operation through insulating transformers or over a carrier current channel. A separate additional metering channel is recommended for readings directly associated with a control function, or if a continuous reading of a selected quantity is desired.

1. The system can be expanded by simple addition of "point" relay cases in previously drilled switchboard units. This expansion can be either additional points or additional outlying stations.
2. Any type of channel can be used by changing the "line" case.
3. The system can be furnished for either 48 volts or 125 volts, d-c.
4. The system is built as an integral part of the switchboard with all devices harmonizing with standard switchboard equipment.

Digest of paper 49-272, "Space Code Selector Supervisory System," recommended by the AIEE Substations Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Electrical Starting of Aircraft Jet Engines

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THE NECESSITY for much greater cranking power to start aircraft jet engines has led to problems radically different from those encountered in starting reciprocating engines. Although early considerations indicated no promise for the use of electrical means to start aircraft jet engines, the development of the constant-current power supply characteristic has completely changed the original evaluations.

Recently developed constant-current aircraft jet engine starter power supplies are equipped with carbon-pile current and voltage regulators. This fact simplifies maintenance and supply problems by permitting the use of standard aircraft generators and other components which already have wide application in present-day military and commercial installations. The adaptability of carbon-pile regulators to various operational requirements makes it possible for a single generator to supply constant 28-volt d-c power, constant 120-volt d-c power, and constant-current power over a wide range of ceiling voltages. It is therefore possible to design a single-ground power supply, equipped with carbon-pile regulators, to service and start any present-day aircraft employing a d-c electric system. Present standardization calls for 1,000 amperes at a ceiling of 30 volts. Power supply systems operating at higher ceiling voltages suggest advantages resulting from smaller current requirements for a given power output and present no complications over a 30-volt system.

Figure 1 shows a self-contained portable gasoline-engine-driven constant-direct-current power supply for starting aircraft jet engines which was developed for the Bureau of Aeronautics, Department of the Navy. This unit has a ceiling voltage adjustable between 150 and 250 volts and is capable of delivering sufficient power to obtain 60 horsepower output at 2,000 rpm from its companion-piece, the air-borne starter motor shown in Figure 2.

The ground power supply is 71 inches long, 40 inches wide, stands 37 inches above the floor, and weighs 840 pounds. The compact dimensions and small weight of this unit permit excellent maneuverability about grounded jet aircraft. The prime mover consists of a 4-cylinder horizontally-opposed air-cooled gasoline engine. One end of the crankshaft drives a Sirocco-type centrifugal fan for engine cooling only. A separately-excited d-c generator with integral cooling is flange-mounted to the opposite end of the crankshaft. This generator operates as a 28-volt motor to crank the prime mover, operates as a 28-volt d-c generator to charge a self-contained battery at low engine speeds, and supplies constant 300-ampere d-c output to power aircraft jet engine starters. Excitation for the generator is supplied by a variable-voltage self-cooled exciter coupled to the commutator end of the generator through a splined quill-shaft.

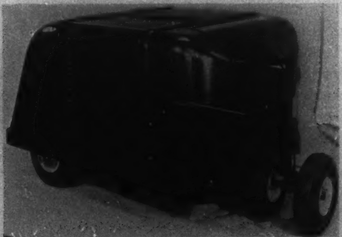

Figure 1. Portable jet starter power supply delivers 300 amperes constant current at ceiling voltages between 150 and 250 volts

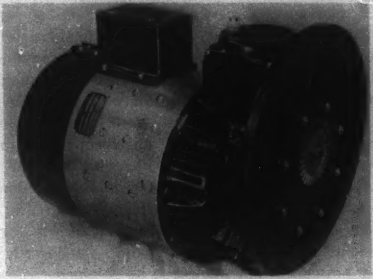

Figure 2. Air-borne electric jet engine starter motor delivers 60 horsepower at 2,000 rpm and 175 volts

An operators' control panel is exposed by lifting a small cover at the generator end of the unit. The prime mover operates at 1,800 rpm in a standby condition, being increased to 3,600 rpm immediately prior to initiation of an aircraft jet engine cranking cycle. After the point of self-sustained jet engine operation, appropriate sensing devices cause the main contactor to open and automatically return the prime mover to the 1,800-rpm standby condition.

The air-borne jet engine starter shown in Figure 2 is a series motor weighing 97 pounds and is provided with a series electromagnet for extension of the 30-tooth starter jaw. High-speed motion pictures of jaw engagement from rest during a starting cycle showed only 12 degrees rotation of the starter jaw before effecting complete and steady engagement with a jaw coupled to a 165 pounds-feet squared inertia load. Satisfactory jaw performance was also demonstrated by a series of tests which simulated false turbine start conditions.

Digest of paper **49-219**, "D-C Power Supplies and Starters for Starting Aircraft Jet Engines," recommended by the AIEE Air Transportation Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Pacific General Meeting, San Francisco, Calif., August 23-26, 1949. Not scheduled for publication in AIEE *Transactions*.

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Rectifier Transformer Characteristics

AN AIEE COMMITTEE REPORT

MANY different converter circuits have been developed. They may be classified as single-way or double-way, depending upon the polarity of the current pulses which flow in the d-c windings of the rectifier transformer. Single-way circuits are most common in power rectifiers and require a transformer with an even number of d-c windings per a-c winding in order to avoid saturation of the transformer core because of the direct current flowing in each one of the windings.

In a double-way circuit opposite directions of current conduction in the d-c windings occur in alternate half cycles. The d-c winding current, therefore, contains no direct component and the a-c winding will conduct the reflected d-c winding current. Since the a-c and d-c windings are active simultaneously, their kilovolt-amperage will be equal and the winding arrangement similar to the conventional transformer. It is, therefore, evident that the copper economy of the rectifier transformer for double-way circuits is greater than for single-way circuits. In the single-way circuit it is necessary that the winding arrangements be carefully interlaced and symmetrically disposed if satisfactory operation is to be obtained.

Rectifier transformers are subject to more severe stresses at more frequent intervals than are power transformers. Mechanical strength, therefore, must be of the highest order and the structure must be of such a nature as not to yield or fail under repeated stressing. Inasmuch as the net axial magnetic force between a-c and d-c windings is proportional to the net displacement of magnetic centers, it is desirable to have both windings as free as possible of taps. On the larger ratings it has become common practice to take care of direct voltage control by auxiliary means, such as autotransformers or voltage regulators, in order not to impair the rectifier transformer design as regards unbalanced magnetic forces.

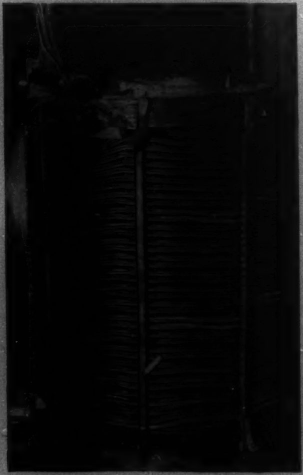

Figure 1. Interwound helical coil, comprising two d-c windings, damaged by repeated arc-backs

Part of a 3,000-kw 600-volt delta-parallel double-Y rectifier transformer, this unit is an older design and not representative of modern equipment

The voltage of the d-c windings, the reactance, and the resistance of the transformer largely determine the electrical performance characteristics of the rectifier. Transformer name-plate data are generally sufficient to approximate the performance of a given circuit. More accurate calculations can be made when other factors are known.

The increase in fault current duty of rectifier transformers over power transformers is a very important consideration in a satisfactory design. Fault current magnitude is largely a function of the transformer voltage and reactance together with the arc drop of the rectifier elements. Regulation of the rectifier is a direct function of the transformer reactance while fault current magnitude is an inverse function of the transformer reactance.

The maximum value of fault current in the d-c winding of a transformer during arc-back, for a 600-volt rectifier of normal regulation, will be of the order of 50 times the normal rms current for the winding. Core saturation due to an arc-back is effective in reducing the mechanical forces acting on windings of a transformer during long faults.

In one early test, a 3,000-kw 600-volt delta-parallel double-Y rectifier transformer was tested to destruction by the repeated application of artificial arc-backs in the laboratory. Figure 1 shows one inner coil, comprising a pair of interwound helical d-c windings, from this transformer. It will be noted that the deflections between radial spacers are greatest at the ends of the coil and are in opposite directions, that is, toward the center from each end. Electrical failure occurred at the bottom end, presumably because there the deflection between radial spacers was large enough to cause a winding-to-winding short circuit. Over-all mechanical failure of the coil also ensued as a result of the failure of the insulating member at the top end of the coil.

The accumulated data from laboratory tests and field experiences have contributed greatly to the art of rectifier transformer design and manufacture. These data have repeatedly substantiated the magnitude of fault currents to be expected, the destructive effects which result from these fault currents, and the need of adequate protective switchgear for use with the transformer.

Digest of paper **49-271**, "Rectifier Transformer Characteristics," recommended by the AIEE Electronic Power Converters Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

Personnel of Rectifier Transformer Subcommittee, AIEE Electronic Power Committee: R. A. Nelson, General Electric Company, Pittsfield, Mass.; F. D. Kaiser, Westinghouse Electric Corporation, Sharon, Pa.; W. C. Sealey, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.; A. J. Maslin, Chairman, Westinghouse Electric Corporation, Sharon, Pa.

Governor Performance Specifications

A. F. SCHWENDNER   WAYNE ASTLEY

THE RECENTLY issued specification on Prime Mover Speed Governing for steam turbines intended to drive electric generators, rated 500 kw and up, includes definitions and descriptions of terms relating to governor functions and standards of performance. This article is intended to show the application of the terms and definitions to modern speed-governing systems and to indicate how the systems meet or can be made to meet the requirements of the performance specifications.

Figure 1 illustrates an oil type of governor. In both this and the flyball type of system (in accordance with the definitions), element number *1* is the speed governor, elements number *2* are the speed-control mechanism, element number *3* is the governor-controlled valve, element number *4* is the speed changer, and element number *5* is the load limit. Elements of other types of systems can be similarly grouped.

Steady-state speed regulation is the change in sustained speed expressed in per cent of rated speed when the power output of the turbine is gradually reduced from rated power output to zero power output with identical settings of all adjustments of the speed-governing system. A careful analysis of the oil governor and the interrelationship of its parts indicates that the regulation may be changed by modifying the ratio of the return linkage lever which, for a given valve travel, controls the variation of spring tension on the power amplifying piston 2_2. Analysis of the flyball system indicates that the regulation may be changed by changing the lever ratio of any of the power amplifying devices or the spring scale of the governor itself.

Steady-state incremental speed regulation at a given steady-state speed and power output is the rate of change of the steady-state speed with respect to the power output. In the systems shown, the governor's response to a speed change will be identical at any load point when operating at rated speed. The incremental regulation is dependent primarily on the design of the governor-controlled valve and the resultant flow-versus-travel characteristics.

Dead band is the total magnitude of the sustained speed change within which there is no resulting measurable change in the position of the governor-controlled valves. For turbines in excess of 5,000 kw, the motion of the governor-controlled valves must be reversed with a speed change not greater than 0.06 per cent of rated speed. Analysis of the oil governor shows that the control pressure required to reverse the motion of the servo motor 2_4 and the impeller pressure corresponding to a 0.06 per cent change in speed are both fixed. It is then necessary to select a cup valve with an area such that the required control pressure change is obtained as a result of the impeller pressure change on the bellows. As an alternative, the area of the bellows could be changed. Similarly, the flyball governor will have to be designed to travel a sufficient amount with a 0.06 per cent change.

Stability and overspeed requirements can be obtained only by considering the turbine characteristics as a whole and by building into the governor system the specified rate of response. This means the investigation of each unit, the selection of relay areas sufficient to pass the required quantities of oil, and oil pumps of capacity.

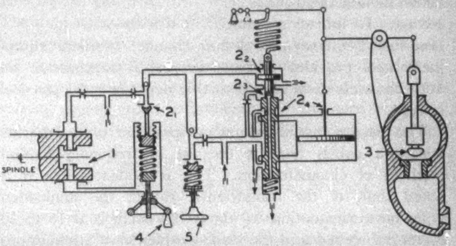

Figure 1. Hydraulic type of speed-governing system

Range of speed changer adjustment in the oil governor is determined by the extent of travel of the speed changer *4* and the scale of the spring. To change the range of the speed changer the spring scale must be changed. The flyball governor is equipped with a speed changer whose range is determined by the travel of the relay sleeve. To increase the range of the speed changer, it is necessary that the governor be designed for the required increased travel.

Adjustment of speed regulation with the turbine in operation is optional and is accomplished by moving the fulcrum point of the follow-up linkage in either type of governor.

The load-limiting device in the oil governor establishes a given pressure in the force amplifier 2_2. Any attempt by the governor to drop the pressure in this chamber and increase load is overcome by the closing of the check valve 2_1. An attempt by the governor to increase pressure in the chamber and drop load closes the check valve *5* and the governor retains control. A similar device is used in the flyball governor. The upper end of the adjustable screw prevents the piston from moving below the point for which it is set, and the governor will have full control above the setting of the load limit. This system must permit free travel of the governor so that excessive loads will not be placed on the knife edges.

Digest of paper 49-288, "Governors and the AIEE-ASME Governor Performance Specification," recommended by the AIEE Power Generation Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Two-Channel Submarine Carrier Telegraph System

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A new telegraph system utilizing standard land-line frequency-modulation equipment has been developed for the Key West–Havana cables. It provides two 2-way channels suitable for multiplex or teleprinter operation and can be operated as a metallic circuit over any two of the three installed cables in case of cable failure.

A NEW 2-channel carrier telegraph system for short submarine telegraph cables has been developed for the Western Union Key West–Havana cables, about 100 nautical miles in length and with attenuations up to 80 decibels at 1,000 cycles per second. It utilizes standard land-line frequency-modulation channel terminal equipment and provides 50-cycle telegraph transmission on both channels without appreciably degrading the physical circuits.

The narrow useful frequency spectrum on submarine telegraph cables restricts the use of frequency-division methods of channelization. This is evident when it is noted that, of the transatlantic cables, the nonloaded types have attenuations of about 100 decibels at 15 to 20 cycles per second and the loaded cables have attenuations of the same order at 100 cycles. Where channelization is desirable on long cables use is made of electromechanical time-division multiplex methods.

The submarine telegraph cable network also includes cables of shorter lengths, ranging down to 100 nautical miles or less, which serve as connecting links in long circuits or provide direct traffic facilities to or between islands. The connecting links originally were, and in some cases still are, operated at the speeds of the related long cable sections and thus below their potential signaling capacities. The direct facilities have been developed more fully under the compulsion of increasing traffic loads.

In recent years signal-shaping amplifiers have been installed rather generally on the connecting cables of some cable systems making higher physical-circuit operating speeds available. As a result, channels of separate long cables may be combined for transmission on the connecting links through use of modern time-division multiplex methods involving devices such as the channel repeater. Low-frequency carrier circuits are also in use on a number of short cables in various cable systems. The limited use of carrier in the Western Union cable plant includes one early installation in which the cable is 326 nautical miles in length; the physical circuit can be operated at dot frequencies up to 30 cycles; the superposed circuit, in one direction only, with a carrier frequency of 90 cycles, is operated at a speed of 31 cycles. Another application of carrier involves cables about 100 nautical miles in length and provides a one-way channel with a carrier frequency of 300 cycles and an operating speed of 35 cycles.

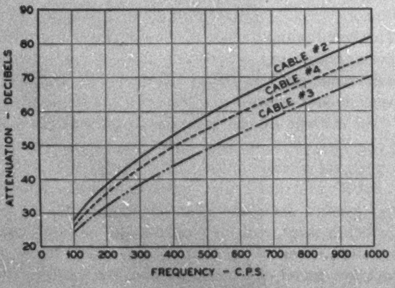

Figure 1. Attenuation of Key West–Havana cables

Although the traffic requirements prevailing from time to time have been satisfied in the manner outlined, the present utilization of the useful frequency spectrum of the short cables cannot be regarded as efficient. Consideration of means for attaining optimum efficiency inevitably leads to time-division multiplex methods. Because of mechanical limitations the multiplex system long in use on land line and cable d-c telegraph circuits is not suitable for the high speeds implied. Perfection of electronic time-division systems, currently under intense development for radio applications, may provide the ultimate solution at the bottom of the frequency spectrum also. In the meantime, modern frequency-division methods and equipment, already in an advanced stage of development, are available, and a recent carrier installation on the Western Union Key West–Havana cables has yielded a substantial increase in message capacity.

THE KEY WEST–HAVANA CABLES

Western Union wire facilities to Cuba consist of three single-core submarine cables between Key West and Havana, each about 100 nautical miles in length. The

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Full text of paper **50-10**, "A 2-Channel Carrier Telegraph System for Short Submarine Cables," recommended by the AIEE Committee on Telegraph Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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physical circuits are operated as ground-return polar differential duplexes. Because of the high cable attenuation, the receiving terminals utilize the principle of the well-known Gulstadt vibrating relay to insure adequate sensitivity for the low-level received signals. The normal assignments are 3-channel multiplex circuits.

For some years the physical circuits were supplemented with two 1-way southbound carrier channels, each having a carrier frequency of 300 cycles per second and utilizing amplitude modulation. One channel was superposed on two of the cables as a metallic circuit, the second as a ground-return circuit on the third cable. The high attenuation of the cables and the state of the carrier art when the original system was installed made it impracticable to provide additional channels through the use of higher frequencies.

Recently a need for additional telegraph facilities to Cuba became evident. In view of improvements in carrier telegraphy it was decided to undertake the development of a new system which would provide two 2-way channels of higher transmission quality. The type *C-3* carrier system resulting from that development, and described in this article, was installed at Key West and Havana in the early part of 1949.

CARRIER SYSTEM REQUIREMENTS

When this project was initiated, traffic considerations required that the proposed carrier system should

1. Provide two 2-way channels, each suitable for 35-cycle multiplex operation or for teleprinter operation.
2. Permit operation of the physical circuits as 3-channel multiplexes with the existing differential duplex equipment or as 4-channel multiplexes with resistance-bridge duplex circuits and signal-shaping amplifiers.
3. Be capable of operation as a metallic circuit over any two of the three cables, thus providing some protection against cable failure.

CABLE CHARACTERISTICS

The three Key West–Havana cables, *2*, *3*, and *4 KZ-HVA*, are single-core nonloaded cables lying about ten miles apart over most of their length. Each cable is a composite of several different types of cable. The general characteristics are given in Table I.

Table I. Characteristics of Key West–Havana Cables

Cable	Length, Nautical Miles	Major Core Types*	Total Resistance, Ohms	Total Capacity, Microfarads
2 *KZ-HVA*	105	107/140	988	31.2
3 *KZ-HVA*	98	160/166	675	35.2
4 *KZ-HVA*	96	130/130	775	30.5
Key West Undergrounds	0.89		23	0.15
Havana Undergrounds	4.44		70	2.0

* Pounds per nautical mile of copper and gutta percha.

The receiving earth in all cases is carried back from the office through the underground to the cable hut at the beach on a conductor paired with the cable conductor.

The attenuation and impedance characteristics of the three cables, including the undergrounds, are shown in Figures 1 and 2. The attenuation characteristic of any two cables taken as a metallic circuit may be approximated by averaging the values of the selected cables. With attenuations of 38 to 46 decibels at 300 cycles, and 70 to 82 decibels at 1,000 cycles, these cables approach the attenuation characteristics of 16-gauge paper-lead cable. The total attenuation is about three times that encountered in a typical land-line carrier section. As a metallic circuit, the conductors of the submarine section are unbalanced and unpaired, conditions which, in a land-line carrier system, usually result in intolerable interference levels but are here largely offset by the shielding effect of the sea water.

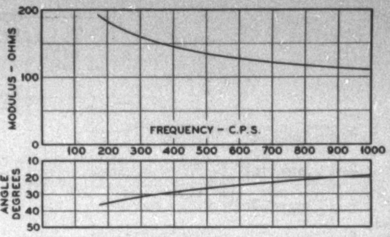

Figure 2. Sending-end impedance of Key West–Havana cables, Key West end

DESCRIPTION OF CARRIER SYSTEM

The *C-3* carrier system is shown schematically in Figure 3. It utilizes the frequency-modulation channel terminals[1] standardized by Western Union and widely installed in the land-line carrier systems.

The channel terminal comprises two units, one a sending-receiving filter panel, and the second a transceiver which combines the electronic transmitting and receiving functions. Standard midchannel frequencies are used, 375 and 525 cycles for southbound transmission, and 825 and 975 cycles for northbound transmission. The channels have a band width of 80 cycles and are spaced at 150-cycle intervals, with one channel omitted to facilitate directional separation. Frequency modulation of the transmitted carrier is accomplished by raising and lowering the midchannel frequency 35 cycles to send spacing and marking impulses, respectively. This type of channel terminal is designed for operation at a maximum dot frequency of 35 cycles per second in land-line installations where two or more carrier systems may be operated in tandem. In such cases, the additive effects of successive channel filters narrow the channel band width and thus limit the maximum signaling speed. The present application involves only a single carrier section, and the channel band width is sufficient under these conditions for a dot frequency of 50 cycles per second provided other factors, such as interference levels, are favorable.

The channel terminals as used in the *C-3* system are standard in most respects. Minor wiring modifications in the transceivers adapt them to the power supplies at Key West and Havana and discard the half-duplex and repeater facilities which are not required in this instance.

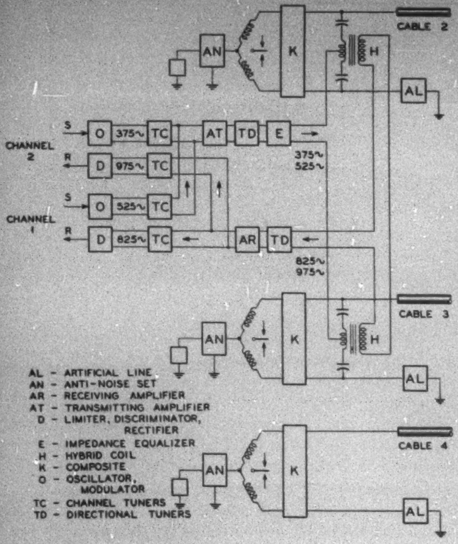

Figure 3. Block diagram of carrier system terminal

In the standard channel terminal, the sending and receiving channel carrier frequencies are alike, while in the *C-3* system the sending and receiving frequencies differ.

Other components of the *C-3* system are the hybrid coils which couple the carrier equipment to the cables, and the receiving amplifier, both of standard land-line type; sending amplifier, directional separation filters, impedance equalizer, antinoise set and composite, and leg circuit equipment, all of special design.

Directional separation of the channels is secured in part by frequency discrimination and to a lesser degree by the duplex balancing action of the hybrid coils. With different channel frequencies in the two directions, some directional discrimination is provided by the channel filters. The additional frequency discrimination required is obtained by the use of separation filters with cutoff in the 150-cycle guard band located between the northbound and southbound channel frequencies. Characteristics of the channel receiving filters and the receiving separation filters are shown in Figure 4. The characteristics of the corresponding sending filters are generally similar. With cable attenuation up to 80 decibels, it is necessary to provide a total maximum discrimination of 110 decibels between sending and receiving channels to maintain crosstalk interference at 30 decibels below the received signal level. Under practical operating conditions, the discrimination resulting from the balanced hybrid coil arrangement may not be more than ten decibels. The discrimination supplied by the channel filters amounts to about 80 decibels, nominally leaving 20 decibels to be provided by the separation filters. However, the channel filters do not protect the receiving amplifier, common to both channels, against overload by the sending frequencies and their modulation products. As shown in the system power level chart, Figure 5, the sending power level is high, about plus 38 decibels per channel or a total of 42 decibels (referred to zero power level of 1.0 milliwatt), and for that reason the separation filters must actually provide discrimination of some 60 decibels.

To provide the high sending carrier level, the transmitting amplifier has greater gain and power output than the corresponding amplifier standard in the land-line system. It consists of two push-pull stages, with three *25C6* tubes in parallel on each side of the output stage, and delivers 17 watts. By using about 20 decibels of combined voltage and current feedback, the total harmonic distortion is limited to one per cent, and most of this is at frequencies outside the pass bands of the channel filters.

The cable capacitance combined with the capacitors used to couple the carrier system to the cables result in a highly reactive sending-end impedance at carrier frequencies. For efficient transfer of carrier power to the cables, an impedance equalizer is used which provides a resistive load for the sending amplifier and filter and matches the reactive cable input impedance.

The low carrier receiving levels and the small permissible degradation of the physical circuits impose severe requirements in the suppression of noise from the physical circuits. For this purpose use is made of antinoise sets and composites having the characteristics shown in Figure 6. The antinoise sets are low-pass filters in the apexes of the physical circuits with cutoff at about 200 cycles and providing discrimination of over 60 decibels against carrier-frequency components of the physical circuit signals. The composites provide maximum discrimination against the physical circuit signals at the frequencies of the carrier channels. Thus a total discrimination of over 100 decibels is obtained while the insertion loss in the physical circuits for frequencies below 150 cycles is less than three decibels. Corresponding values in land-line circuits are 50 decibels and 10 decibels.

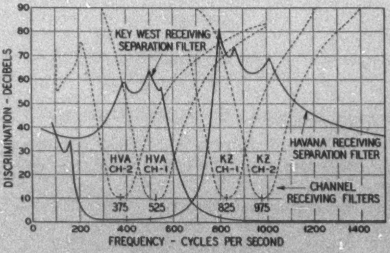

Figure 4. Receiving filter characteristics

High-frequency noise components are generated by the motion of the armatures of the receiving relays of the physical circuits. This noise, unless suppressed, may overload the carrier receiving amplifier. The band-pass separation filter at Havana provides the necessary suppression, which, however, is lacking in the high-pass separation filter at Key West. At that terminal the suppression is accomplished by including in the composites an attenuation section centered at about 2,150 cycles.

In the land-line system, relays for transmitting and receiving have been eliminated in the channel terminals, and the transceivers function entirely electronically with single-current telegraph impulses in the leg circuits. This simplification became practicable in the domestic telegraph plant with the vast expansion of carrier operation and the concurrent decline in d-c grounded and metallic facilities. Circuit extensions at Key West and Havana are not yet compatible with such simplification, and the *C-3* system includes intermediate relays in both the sending and receiving legs, so that leg-circuit operation may be either single-current or polar. As shown in Figure 7, each leg circuit is provided with sounder and key and means for connecting a teleprinter for monitoring purposes. Jacks in the leg and intermediate relay circuits permit the insertion of a meter for measurements of current and signal bias.

While the *C-3* system is designed primarily for operation on a metallic circuit, it is evident that in the event of interruption of two of the three cables, ground-return operation on the remaining cable is greatly to be desired. Networks simulating the cable and artificial line impedances are provided at each terminal and arranged to be substituted for the second cable to maintain proper impedance relations for ground-return operation.

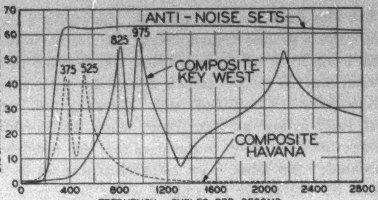

Figure 6. Frequency characteristics of composites and antinoise sets

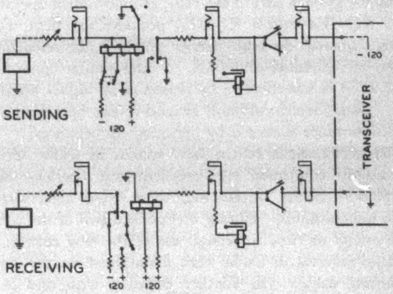

Figure 7. Schematic of telegraph leg circuits

TEST AND PERFORMANCE DATA

In Cuba, the submarine cables land at Cojimar and are extended to Havana in underground cable, a distance of 4.44 nautical miles (Table I). The receiving earths are carried back to Cojimar, paired with the corresponding cable conductors. In this situation, satisfactory duplex balances for both the physical circuit and carrier frequencies could not be obtained with any normal adjustment of the Havana artificial lines. The difficulty was solved by inserting in the earth-return conductor at Cojimar a simple resistance-capacitance network which partially matches the impedance of the submarine cable section. Identical networks were installed for each cable. Under this condition, normal adjustments of the Havana artificial lines produce adequate balances at all significant frequencies. An additional advantage of the networks is that the cable and earth conductors of the underground sections are more nearly balanced against extraneous interference. At Key West, where the underground circuits are short, there was no duplex balance problem encountered in operation.

With the use of metallic circuit connections, the noise level from all available sources at the input end of the receiving side of the transceiver is 35 to 40 decibels below the signal as it is received at Havana, and 40 to 45 decibels below the received signal at Key West, depending upon the combinations of cables used. With the carrier superposed on any two of the three cables, excellent margins are provided for teleprinter, 33-cycle polar ticker, and 3-channel multiplex operation. With 50-cycle 3-channel multiplexes on both channels, the margins are

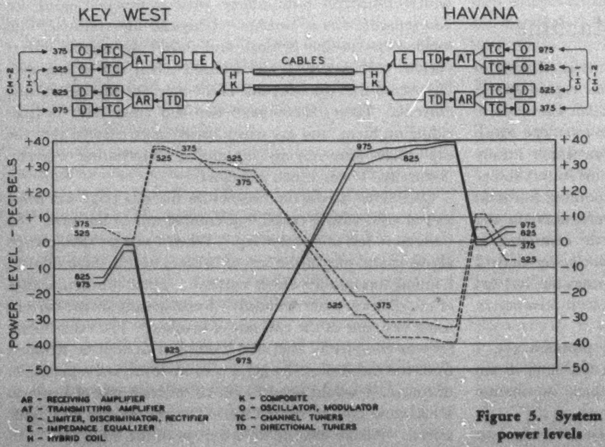

Figure 5. System power levels

much better than those obtained on the physical circuits.

Set up as a ground-return circuit, the carrier noise level ranges from 30 to 40 decibels below the received signal at Havana, and 20 to 30 decibels below the received signal at Key West. Compared with Havana, the received signal level is low at Key West, since the northbound channels utilize the top frequencies and are more heavily attenuated; also noise from extraneous sources is higher because the cables are in shallow water for a greater distance at the Key West end of the route. The noise measurements were made during the month of February; somewhat higher levels of natural disturbances, such as lightning, may be expected in the summer months.

For the greater part of the year, ground-return operation on *3 KZ-HVA* and *4 KZ-HVA* provides excellent transmission quality on both carrier channels for teleprinter, ticker, or 3-channel multiplex. Under similar conditions, *2 KZ-HVA* is less effective by reason of its higher attenuation. Some deterioration of ground-return operation during the summer is caused by lightning disturbances.

The performance of the new system in traffic service has amply confirmed the excellent test results. Since completion of the installation, there have been several cable interruptions. During one period, two of the cables were out of service. Through use of the new carrier, all essential services to Cuba were maintained on the single remaining cable. On another occasion with one cable interrupted, the new system was superposed on one cable while an old-type 300-cycle channel was operated southbound on the second cable, with excellent performance.

Traffic experience with ground-return operation of the new system has developed a special circuit arrangement of some practical importance. When a cable is out of service because of an interruption or fault, that cable, under favorable conditions, may be utilized with an operating cable to provide a regular metallic circuit connection for the carrier, thus retaining the low interference levels normal with metallic operation. The nature and location of the fault and its effect on the duplex balance of the faulty cable determine the suitability of this arrangement in specific situations. If the fault is so near to one terminal that the carrier duplex balance cannot be restored readily, the ground-return connection would be used for the carrier at that terminal while the metallic connection could be used at the distant terminal. If the fault is in the midsection of the cable, the metallic connection can be utilized at both terminals.

Operation of the polar differential duplex physical circuits is not affected appreciably by the new carrier equipment. The field tests indicate that 4-channel 66-cycle multiplex operation will be feasible as a resistance-bridge duplex with signal-shaping amplifiers.

The Key West–Havana cables utilize core types (Table I) typical in general of short submarine telegraph cables. Although the *C-3* carrier system was developed for specific conditions it is applicable to similar cables for distances not exceeding about 100 nautical miles or attenuations not greater than 80 decibels at 1,000 cycles per second. Modified systems such as one 2-way channel or one to four 1-way channels would be suitable for cables of somewhat greater attenuation.

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1. A Frequency Modulation Telegraph Terminal Without Relays, F. H. Cusack, A. E. Michon. AIEE *Transactions*, volume 66, 1947, pages 1165–71.

Electrical Essay

Half and Whole Solution for Commutatorless D-C Machine

Perhaps I was getting over my head in my inventions on electrostatics made while I was doing that repair job on the Van de Graaff generator at the Research Laboratory. I am glad to be back down here on the test floor again where I work with motors and generators which I fully understand. However, I still have my inventive ability tuned to the stars, and I am working on nothing less than the problem of getting rid of the commutators on d-c machines. Needless to say if I get rid of the commutator, I'll also get rid of the brushes and brush-rigging since I am not going to have the brushes ride on empty air, ha! ha! Also, needless to say that will be a wonderful advance in the art of d-c machines.

While I haven't completely solved the problem yet, I have made such great progress these last few days I am sure that the people who have taken such an intense interest in my inventions will want to hear about it.

There appeared yesterday on the test floor a very curious hybrid sort of machine. On one side, it was direct current with full-fledged commutator with complete rigging for two separate sets of brushes. I hooked my voltmeter and oscilloscope to the brushes and found top-quality direct current. However, I was amazed when my prying eyes discovered that the back side of the machine was alternating current. There, there were two slip rings with brushes riding on them, and my trusty oscilloscope showed that the slip rings were giving top-quality alternating current. Naturally, I was much intrigued.

Connected across the brushes on the slip rings was some sort of coil, with a center tap coming out of the case. So I began to test this center tap. When I put my oscilloscope across it and one of the sets of brushes on the commutator, I found top-quality direct current. Then the significance of my discovery hit me hard. I was getting direct current using only one of the two sets of brushes. The other brush set was completely idle, and could just as well be stripped from the machine. To get a commutatorless d-c machine, of course, I would need to get rid of both sets of brushes. I had now got rid of one set. The problem is now half-solved. All we have to do is get rid of the other set.

Will some reader contribute his half of the invention by getting rid of that other set of brushes?

P.S.: Just after writing the foregoing, I suddenly discovered how to make a commutatorless d-c machine, and completely. It is along a little different line, and I thought I had better get this postscript in before my readers spend too much time on the half-solution.

I start with an a-c machine, where a d-c winding on the rotor gives a succession of north and south poles. As the lines of force from a north pole cut the sides of a coil in the stator, it generates a certain voltage. However, the lines from the following south pole cut the coil sides and generate voltage in the opposite direction. Thus we get alternating current in the coil.

Now! After the north pole has finished cutting the coil-side and before the south pole has begun, let us reverse the direct current in the rotor. Then the following south pole changes to a north pole, and the voltage it generates by cutting the coil will have the same direction as that produced by the preceding pole. Continue this way, reversing the rotor current just after each pole has done its work on the stator coil. Then the voltage in the stator coil will always be in the same direction, and if a filter is interposed we should have top-quality direct current.

J. Slepian, Alter Ego

When the author was working on the test floor of the Westinghouse Electric Corporation many years ago, a young engineer independently made the second of the two inventions described in the foregoing, and persuaded his superior to authorize the building of a small model. The engineering report describing it, however, was entitled, "A New Method for Generating Double-Frequency Current."

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Answers to Previous Essays

Self-Running Electrostatic Motor. The following is the author's solution to a previous essay (*EE, Mar '50, p 247*).

You'll avoid getting into such fixes in the future, Alter Ego, if you'll refrain from talking about the force exerted by the electric field on charges or charged bodies placed within matter, as if the notion of such force had any uniquely verifiable meaning.

Coulomb's law and the Lorentz force equation have meaning for small enough charged bodies in empty space. For such bodies, **F**, *q*, **E**, and **B** may be defined operationally and uniquely. However, the definitions used for empty space cannot be carried over directly to within matter. We shall see in later essays how we may define **E**, **D**, **B**, and **H**, and even *ρ*, the charge density within material, but **F**, supposedly the direct action of the electric field on the charges introduced into the material, is another matter.

So far, in this discussion of this and the preceding electrical essay, "Electrostatic Space Ship," the vectors **F**, **E**, **B**, the scalar *q*, have meaning only for small enough bodies in empty space, and sufficiently far away from other material bodies. It is only in this domain of observable phenomena that Coulomb's law and the Lorentz force equation have verifiable meaning. If we wish to extend electromagnetic theory to the interior of extensive material bodies, new operationally meaningful definitions of the field vectors, and charge and current density must be given since the definitions given for particles or sufficiently small bodies are clearly without verifiable meaning inside of extensive matter. It is possible to give such generally uniquely meaningful definitions of the electromagnetic field and charge and current densities, and the author hopes that in future essays such definitions will be presented. However, in the author's opinion, it is not possible to define in any significantly unique way the ponderomotive force density, and again the author hopes that in future essays this will be brought out.

Going from small-charged-body electromagnetism to that for extended material bodies is similar in some ways to going from Newtonian particle dynamics to rigid body or continuous medium mechanics. In this last case Newton's laws for particles are not sufficient. We must invoke new and independent principles, such as the principle of virtual work, or D'Alembert's principle.

Similarly, in the electrical case, to systematize or put in order the electromechanical effects for extended bodies we need some additional principle over and above Coulomb's law and the Lorentz force equation. Most investigators have chosen the principle of conservation of energy for this purpose. They assume the existence of an energy function which, for the particular electromechanical system, is a function of the electrical and mechanical parameters which specify the state of the system, and which the investigator may vary at will. The change in value of this energy function as the parameters are varied is set equal to the work done by the investigator in changing the parameters, and thus an expression for the force appropriate to any particular independently variable parameter may be obtained.

Certainly no objection can be raised to this procedure. If we apply it to Alter Ego's machine, it would appear that whatever the energy function may be, it must be independent of the position of the belts along their pulleys, since shifting the belts along themselves appears in no way to change the electrical or mechanical configuration. Hence it appears that the force tending to move the belts is zero. However, many investigators have gone further. They assume (unjustifiedly) that the total energy of the system can be resolved in some significantly unique way into the sum of a purely electrical part and a purely mechanical part. Then assuming that the system changes continuously from one state to another, with great mathematical skill, they transform the rate of change of the hypothetically unique electrical part of the energy into an integral over the moving parts of the system of some vector expression multiplied scalarly into the vector velocity of the material at each point.

There is no evidence that this transformation of the rate of change of the electrical part of the energy, dU_e/dt, into an integral of the form

$$\frac{dU_e}{dt}=\int\int\int \mathbf{f}_e\mathbf{v}\,d\tau \qquad (1)$$

is unique. In fact, we must expect the contrary generally to be the case. Nevertheless, the particular factor $\mathbf{f}_e$ which the particular investigator uses to multiply $\mathbf{v}$ in equation 1 is then called by him the electric ponderomotive force density. Presumably it will be equilibrated by a mechanical force density arising in a similar way from the presumably uniquely determinable mechanical part of the total energy. An example of $\mathbf{f}_e$ so calculated was given in last month's discussion (*EE, Mar '50, pp 247–9*) of the preceding essay (*EE, Feb '50, p 164*).

Generally it consists of a term, $\rho\mathbf{E}$, plus more complicated expressions deriving from the so-called electrical part of the energy. Alter Ego knew only of the $\rho\mathbf{E}$ term, and believing that the only effect of the inerteen oil would be to reduce the intensity of the field $\mathbf{E}$ which would otherwise have been produced in air by the charges on the belts, came to the conclusion that there would be a net force tending to move the belts.

If Alter Ego had studied his books further, he would have discovered that they assert that there will also be "ponderomotive forces" on the oil, such as those given by the second and third terms of equation 4 in the discussion of the preceding essay. Taking into account these forces, Alter Ego would have discovered that he could not expect the oil to lie level as he shows in his Figure 1, but that it would heap up where the belts enter the oil surface. Also, Alter Ego would have been puzzled by the third term, $\left(\frac{1}{8\pi}\text{grad } E^2\frac{dk}{d\sigma}\sigma\right)$, of equation 14 in the discussion of the preceding essay, which contains the coefficient of variation of the dielectric constant k with density σ, in spite of the fact that in his problem, the oil is essentially incompressible. If he were a sufficiently good mathematician to take into account this force, he might be surprised to discover that no matter what value he took for the coefficient, $dk/d\sigma$, he would come out with the same configuration of the oil, since the term in question would give surface forces on the oil which would just balance the volume forces arising from this term. He might then wonder whether this so agreeably self-cancelling ponderomotive force had any unique validity or reality.

He might observe that, after all, these forces were all calculated by using the energy principle with an arbitrarily assumed division of the energy into an electrical and mechanical part, and that even with this arbitrary division, the forces were not determined uniquely by the mathematics. He might conclude then, that since these uncertainly determined ponderomotive forces were calculated from the principle of energy, he might just as well use this principle to solve his problem directly. For his electrostatic motor, as Alter Ego realized, with zero continuous current flowing, the principle of energy would predict that belts would not move. Any detailed calculation with "ponderomotive forces" also calculated from the energy principle could give no further information and must of course lead to the same conclusion.

Now for the patient reader who has come this far, the author has a surprise. The author believes that with any actual insulating oil, including Westinghouse inerteen, the electrostatic motor of Alter Ego *will run*, provided the friction at the pulleys and the stiffness of the belts is sufficiently reduced. No oil is prefectly insulating, and therefore a small continuous current will flow to the moving belt by way of the corona points, to replace the belt charge lost by electrical leakage or conductance of the oil. Hence there will be a continuous electric energy input into the system, and the principle of energy cannot be used to deny the possibility of a mechanical energy output from the moving belts.

In the language of "ponderomotive forces" the "attraction" of the oil for the charges entering will be less than the "attraction" for the charges leaving because the charges leaving will be reduced in amount by the electrical leakage of the oil. Any one who has watched oil being tested in the usual oil test cup knows that there is considerable continuing motion of the oil at quite a bit less than the breakdown voltage. The possible operativeness of Alter Ego's electrostatic motor is daily being demonstrated in testing laboratories.

There is another way of arriving at "ponderomotive forces" within material, but still not uniquely, namely through Maxwell's electromagnetic stress tensor. The author hopes to discuss this in some later essay.

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Polyphase Windings. The following is the author's answer to a previous essay (*EE, Feb '50, p 165*).

Figure 1 shows how the stator winding was rearranged. As three slots had to be left empty, I took six slots at 60 degrees around the circle, and left disconnected one copper bar in each, these being the top bar in slots *100*, *200*, *300*, and the bottom bar in slots *50*, *150*, *250*. The phase groups were then arranged as shown in Figure 1.

It will be seen that for the successive phase-pole groups I took five top and six bottom, and six top and five bottom conductors. The coil span which was 1 to 16 in the original winding was now 1 to 17 on 6, and 1 to 18 on 12 of the 18 poles of the reconnected stator. This caused no mechanical difficulty; it was only a matter of opening the ends of the bars a little more to reach over the slightly wider span. Though physically unsymmetrical, it resulted in an electrically symmetrical winding.

Each phase has two parallel paths. For phase *A*, for example, path *A*, in this arrangement, would go around the circle six times and path A' only five times, but if we come out at the back half way through the sixth round with top conductor in slot *139*, we have been $5^1/_2$ times around and have half of the phase conductors in series. We now take path A' five times around, coming out in front with the top conductor of slot *22* and take it across and pass it under the frame to join bottom conductor of slot *156* and complete our $5^1/_2$ times around the stator, with the half round left over from the sixth round of path *A*. Thus we have two equal paths in parallel as required. The extra resistance introduced by the interconnecting cable is negligible and balanced by an equal cable which brings the end of path *A* from top to bottom of the frame where all leads come out to the terminal box. These cables passing under the stator frame from front to back are bunched together for the three

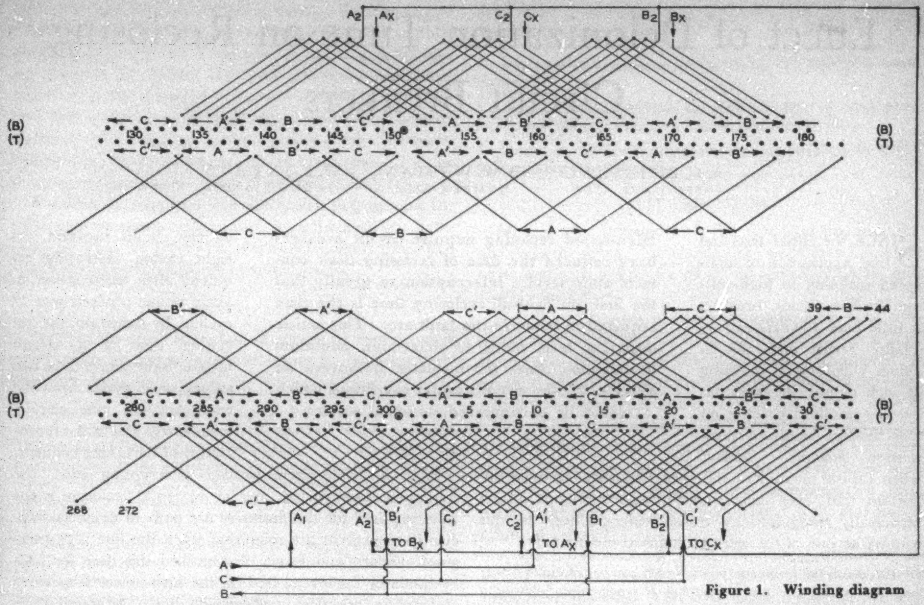

Figure 1. Winding diagram

	T	B	T	B	T	B	T	B	T	B	T	B	T	B	T	B	T	B	
Coil throw		16	17	17	16	17	17	16	17	17	16	17	17	16	17	17	15	17	
A→	1	17	34	51	67	84	101	117	134	151	167	184	201	217	234	251	267	284	
	2																	285	
	3																	286	
	4																	287	
	5																	288	
	6	22	39	56	72	89	106	122	139[d]	156	172	189	206	222	239	256	2 2	289	A_2'→
B'	7	23	40	57	73	90	107	123	140	157	173	190	207	223	240	257	273	290	←B_1'
	8																	291	
	9																	292	
	10																	293	
	11[a]	27	44	61	77	94	111	127	144	161	177	194	211	227	244	261	277	294	
Cl→	12	28	45	62	78	95	112	128	145	162	178	195	212	228	245	262	278	295	
C	13																	296	
	14																	297	
	15																	298	
	16																	299	
	17	33	50	67	83	100	117	133	150[e]	167	183	200	217	233	250	267	283	300	C_2'→
A'	18	34	51	68	84	101	118	134	151	168	184	201	218	234	251	268	284	1	←A_1'
	19																	2	
	20																	3	
	21																	4	
	22[b]	38	55	72	88	105	122	138	155	172	188	205	222	238	255	272	288	5	
Bl→	23	39	56	73	89	106	123	139	156	173	189	206	223	239	256	273	289	6	
B	24																	7	
	25																	8	
	26																	9	
	27																	10	
	28	44	61	78	94	111	128	144	161[f]	178	194	211	228	244	261	278	294	11	B_2'→
C'	29	45	62	79	95	112	129	145	162	179	195	212	229	245	262	279	295	12	←C_1'
	30																	13	
	31																	14	
	32																	15	
	33[c]	49	66	83	99	116	133	149	166	183	199	216	233	249	266	283	299	16	

Disconnected bars—slots: top, 100, 200, 300; bottom, 50, 150, 250

[a] Connected to 178B
[b] Connected to 156B
[c] Connected to 167B
[d] Connected to A2
[e] Connected to C2
[f] Connected to B2

phases, so no heating of the frame results. Again for each phase there are two such cables carrying current from front to back and from back to front as shown by dash-dot lines in Figure 1. The rotor had to be reconnected accordingly, but this offered no difficulties.

It was not, therefore, just a matter of "dividing the winding in the best number of groups"; and, as the reconnected machine has now been working for about four years, if such vibration were to be expected as "would not be withstood by a more modern machine" then this is a very positive proof of the excellence of the old-fashioned design.

The question is whether, in view of the method adopted, any such vibration is really to be expected. It is, of course, well known that certain kinds of regrouping would so affect the flux distribution as to cause serious vibration.

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Effect of Deionization Time on Reclosing Circuit Breakers

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High-speed reclosing impulse circuit breakers have reduced the time of reclosing their contacts after service interruption so greatly that the limit on over-all reclosing time is the time required to deionize the fault arc. This article describes tests made to determine minimum deionization times for insulator flashovers on 69-kv to 230-kv circuits under conditions which would be encountered in actual service.

SINCE the initial tests and trial application of high-speed reclosing to high-voltage tie-line circuit breakers a little over 13 years ago by Philip Sporn and D. C. Prince,[1] high-speed reclosing of such circuit breakers has become standard practice on most modern American transmission systems. Today, when capital investment and operating costs are more important than ever before, high-speed reclosing is almost universally recognized by transmission engineers in this country as one of the most economical methods of

1. Increasing the maximum power which can be transmitted over long high-voltage tie lines without loss of synchronism following a short-circuit tripout.
2. Reducing system disturbance and shock at the instant of reclosing by reconnecting the two parts of the system before they have swung too far apart.
3. Reducing line outage time and improving service to customers.

When Sporn and Prince made their original investigation of high-speed reclosing, the primary limitation was the operating speed of available circuit breakers which, in comparison with present-day circuit-breaker speeds, was relatively slow. The interrupting time from energizing of the circuit-breaker trip coil to interruption on standard high-voltage circuit breakers was eight cycles. The time required after interruption to again reclose contacts was 27 cycles. By definition, the reclosing time of a circuit breaker is the sum of these two values, or 35 cycles from the energizing of the circuit-breaker trip coil to the recontacting of the arcing contacts.

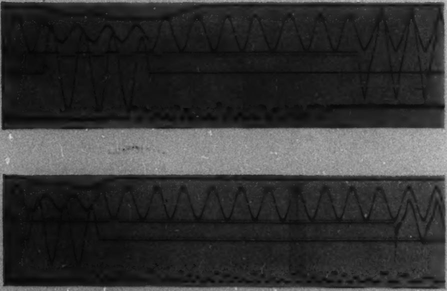

Figure 1. (A, top) Oscillogram of typical reclosing test with reclosing occurring at voltage zero, and (B, bottom) oscillogram of typical reclosing test with reclosing at voltage crest

Trace 1—Trip coil current
Trace 2—Generator voltage
Trace 3—Arc voltage
Trace 4—Short-circuit current
Trace 5—Circuit-breaker travel

With a given circuit-breaker interrupting time, the minimum de-energized time for successful reclosure is the time required for the flashover arc path to deionize sufficiently to prevent arc reignition when the line is re-energized. Sporn and Prince first studied this time for 132-kv insulator flashovers, both in the high-power laboratory and on an operating transmission line. Although their studies showed considerable variation, they found that if the fault current lasted eight cycles, 12 cycles of de-energized time was generally adequate to prevent arc reignition upon reclosure. This gave 20 cycles as the total necessary reclosing time. Special high-speed mechanisms were then developed for 138-kv circuit breakers capable of 20-cycle reclosure and were installed on the 132-kv line between Marion, Ohio, and Fort Wayne, Ind. The results obtained on the initial installation were so promising that manufacturers immediately embarked on a program of developing standard high-voltage circuit breakers with pneumatic mechanisms which could be reclosed in 20 cycles or less. As the interrupting time of the circuit breaker also is important in increasing the maximum power which can be transmitted without loss of synchronism, the interrupting times of standard circuit breakers were subsequently reduced to five and three cycles.

PURPOSE OF PRESENT INVESTIGATION

Until recently, 15 to 20 cycles represented the minimum reclosing time which could be obtained with most high-voltage circuit breakers. However, recent developments in high-speed reclosing impulse circuit breakers effected such a drastic reduction in the time for the circuit breaker to reclose its contacts after interruption, that it became evident that the limitation on over-all reclosing time would most likely be the time required to deionize the fault arc, rather

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Essentially full text of paper 49-221, "Insulator Flashover Deionization Times as a Factor in Applying High-Speed Reclosing Breakers," recommended by the AIEE Committee on Switchgear and approved by the AIEE Technical Program Committee for presentation at the AIEE Pacific General Meeting, San Francisco, Calif., August 23–26, 1949. Scheduled for presentation in AIEE *Transactions*, volume 68, 1949.

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than the circuit-breaker reclosing speed. Tests at Grand Coulee Dam last year on a modern high-speed impulse circuit breaker showed it capable of reclosing 8,700,000-kva faults in 8.6 cycles. The only remaining limitation, therefore, is the required deionization time of the flashover path around the insulator string. With circuit-breaker reclosing times adjusted down to the maximum flashover deionization time, maximum power transmission can be achieved without danger of loss of synchronism.

A general investigation was undertaken to determine the minimum necessary deionization times for insulator flashovers on 69-kv to 230-kv circuits under various conditions which would be encountered in actual service.

FACTORS DETERMINING DEIONIZING TIME

Some of the more important factors to be considered in determining necessary deionization time for insulator flashovers are

1. Magnitude of short-circuit current. The higher the fault current, the larger the amount of ionized gas which will be generated. This will tend to be offset somewhat by the greater amount of turbulence initiated in the surrounding air causing greater swirling and mixing with cool air. Also the magnetic blowout action increases with higher currents tending to loop the arc away from the insulator and lengthen it.

2. Duration of short-circuit current. The longer the fault current flows, the greater the total heat energy liberated. This will tend to be offset somewhat by greater turbulence. Also longer magnetic blowout action with the longer current duration may loop the arc out farther away from the insulator before the current is interrupted.

3. Magnitude and duration of capacitive coupling follow-current which may flow due to induced voltage on de-energized conductor if adjacent conductors remain energized. This assumes particular importance when single-phase reclosing circuit breakers are used.

4. Magnitude and duration of resistance follow-current which may flow momentarily through shunting resistors with some types of circuit breakers which are equipped with shunting resistors in parallel with the main interrupting contacts.

5. Magnitude of re-energization voltage applied.

6. Point on voltage wave at which circuit is re-energized. This determines the magnitude of the surge. If re-energized at a zero point, no surge will be present. If energized at a crest voltage, a surge approaching twice crest voltage will occur. This was not considered in previous investigations and is believed to account for much of the randomness in the results obtained.

Tests were made to determine the effect of each of these. These tests were made in the high-power testing laboratory rather than on an actual power system.

TESTS MADE

In order to cover the range of fault currents normally encountered at the present time or anticipated in the near future, insulator flashover tests were made at approximately 1,000, 8,000, and 25,000 amperes with re-energization potentials equal to the phase voltages of 69, 138, and 230 kv. This range can be obtained readily in the high-power testing laboratory by supplying the fault current from one voltage source and the re-energization potential from a second voltage source.

To be able to apply high-speed reclosing circuit breakers to all types of systems, flashover deionizing data were desired under conditions which would simulate the following types of circuits:

1. Single-circuit transmission line protected with triple-pole circuit breakers.

2. Double-circuit transmission line with both lines on same tower, each circuit being protected by triple-pole circuit breakers.

3. Single- or double-circuit transmission line protected by single-pole reclosing circuit breakers.

TEST PROCEDURE

All arcs were initiated by a fine fuse wire tied over the surface of the string. Standard Locke suspension insulators were used with 5 units for 69 kv, 10 units for 138 kv, and 15 units for 230 kv.

A sufficient number of tests were made under each condition to establish the maximum probable deionizing time. It was felt that much of the randomness encountered by previous investigators was due to the magnitude of the surge which was determined by the point on the voltage wave at which re-energization took place, for while no voltage appreciably higher than normal crest occurs when re-energization takes place at or near a voltage zero, there is an overshoot almost to double when re-energization takes place at the crest. This is well illustrated in the two oscillograms of Figure 1.

A synchronous closing switch capable of accurately selecting the closing angle was used to re-establish the circuit throughout the tests. Test series made under the two conditions with this switch indicated a difference of about three cycles between the deionizing times for closing at voltage zeros and those for closing at voltage peaks, while the data for each condition were quite consistent. It therefore appears certain that much of the randomness reported by previous investigators was due to lack of control of the closing point on the reclosing voltage wave. After proving the effect of this variable, all subsequent tests were made reclosing at a voltage crest to simulate severe conditions.

TRIPLE-POLE RECLOSING—SINGLE-CIRCUIT TRANSMISSION LINE

Figure 2*A* represents a single-circuit transmission line protected by a triple-pole high-speed reclosing circuit breaker without shunting resistors with a flashover from phase 3 to ground over an insulator. A tie line between two systems would have a similar high-speed reclosing circuit breaker at the other end also, but since both circuit breakers would normally be tripped and reclosed simultaneously, the other end may be disregarded in determining the deionizing time of the flashover path *A*. As phases 1 and 2 are opened with phase 3, they may be neglected when simulating this circuit in the high-power laboratory.

Figure 2*B* shows the laboratory circuit used to determine the required deionization time of a flashover arc under this condition. The high-current short circuit was supplied from a 22-kv transformer connected to one phase of the high-power generator with the fault being interrupted by auxiliary circuit breaker. Re-energization potential equal to the phase voltage of 69-, 138-, and 230-kv circuits was supplied from a second transformer connected to the same phase. Any desired number of cycles, as well as the point on the

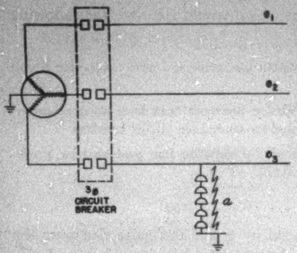

Figure 2A. Single-circuit transmission line protected with triple-pole high-speed reclosing circuit breaker with singleline-to-ground flashover at point A on phase 3

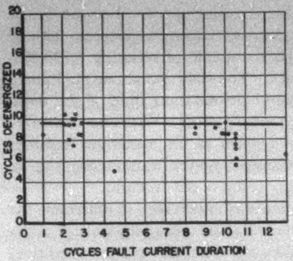

Figure 4. Results of tests varying the duration of fault current prior to interruption showing its effect upon necessary time to deionize arc

Black circles represent restrikes. Open circles represent successful reclosures

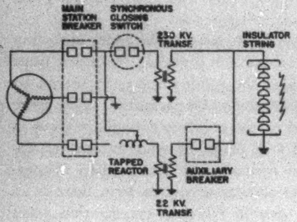

Figure 2B. High-power laboratory circuit used to simulate flashover on single-circuit transmission line

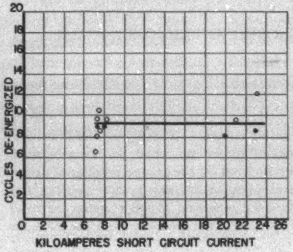

Figure 5. Results of high-speed reclosing tests after flashover on 138-kv suspension insulator

Black circles represent restrikes. Open circles represent successful reclosures. Dividing line just above maximum restriking points represents absolute minimum de-energization time to prevent restrikes

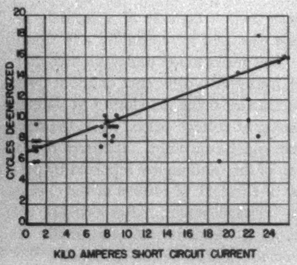

Figure 3. Results of high-speed reclosing tests after flashover on 230-kv suspension insulator

Black circles represent restrikes. Open circles represent successful reclosure. Dividing line just above maximum restriking points represent absolute minimum de-energization time to prevent restrikes

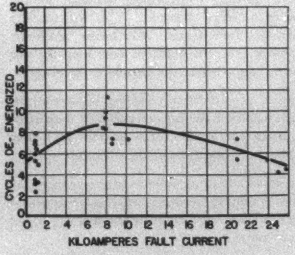

Figure 6. Results of high-speed reclosing tests after flashover on 69-kv suspension insulator

Black circles represent restrikes. Open circles represent successful reclosures. Dividing line just above maximum restriking points represents absolute minimum de-energization time to prevent restrikes

voltage wave, could be selected for re-energization by closing this circuit through the synchronous closing switch in the primary of the high-voltage transformer circuit.

Figure 3 shows a plot of results obtained following 1,000-, 8,000-, and 25,000-ampere flashovers on a 15-unit insulator string with 3-cycle fault duration and 132-kv re-energization voltage, which corresponds to the phase voltage of a 230-kv system. The open circles represent successful reclosures while the solid circles represent restrikes. By plotting the longest unsuccessful reclosing time as the necessary deionization time for that current, it will be noted that the necessary deionization time for 230-kv systems increases linearly with the short-circuit current. By adding three cycles for arc interruption to each of these values for the circuit breaker to interrupt, the minimum total reclosing time for 3-cycle circuit breakers is obtained.

Many systems are equipped with circuit breakers having a longer interrupting time than three cycles. To determine the effect on deionization time of the greater amount of ionized gas generated, a series of tests were made with 10-cycle fault durations and approximately 8,000 amperes. Figure 4 shows the results of these tests as compared with 3-cycle fault durations. This figure shows that the maximum deionization times for 10-cycle faults are about equal to those of 3-cycle faults. This may indicate that the larger amount of ionized gas was offset by the greater amount of turbulence and looping due to magnetic blowout action, which does not agree fully with former investigations.

Figure 5 is a plot of tests taken on a 10-unit insulator string with a re-energization potential of 80 kv, representing phase voltage of 132-kv systems. It will be noted that instead of increasing with higher currents as it did at 230 kv, the deionization time remains approximately constant up to 25,000 amperes.

Figure 6 is a similar plot of tests taken on a 5-unit insulator string re-energized with 44 kv, corresponding to phase voltage of a 69-kv system. It will be noted that for such short insulator strings, the extra magnetic blowout action more than offsets the extra amount of ionized gas generated at high currents. Although Figure 6 shows the results only up to approximately 25,000 amperes, successful reclosure was obtained in 2.3 cycles after 43,000 amperes which indicates this decreasing trend continues at even higher currents. By adding these deionizing times to the circuit breaker interrupting time, the minimum possible total reclosing time will be obtained. How near to these points circuit breakers should be adjusted will depend upon the stability margins of the particular system under consideration.

Many modern high-voltage circuit breakers are equipped with shunting resistors to eliminate overvoltages when interrupting the charging current of long unloaded transmission lines. When interrupting fault currents, the contacts of this type of circuit breaker interrupt the main fault current in either three or five cycles. The shunting resistor current in most such circuit breakers does not exceed 50 amperes and is interrupted by secondary contacts a few cycles later. Figure 7*A* represents a single-circuit transmission line protected by triple-pole circuit breakers equipped with shunting resistors. Figure 7*B* shows the laboratory circuit to simulate insulator flashovers under these conditions. Two separate circuit breakers were used to simulate the two sets of contacts. Figure 8 shows the maximum overvoltage oscillation on various lengths of 230-kv transmission line when they are reclosed at crest voltage by a circuit breaker equipped with shunting resistors.

Figure 9*A* shows the oscillogram of a test in which a 230-kv insulator string was flashed over by an 8,000-ampere arc. After 3.9 cycles, the main short-circuit current was interrupted, leaving a 50-ampere resistance follow current, which continued for 4.7 cycles more. Power was then removed for 7 cycles and reapplied at a voltage crest, and the arc restruck. Figure 9*B* shows an oscillogram of a similar test except that the de-energized time was 8.3 cycles.

A resistance-shunted circuit breaker will reclose in two stages, first through the resistor, then short-circuiting out the resistor. Reclosing on a transmission line through a typical resistance of 2,700 ohms, the first stage will involve no oscillation with transmission line lengths of a mile or more. In general, the overvoltage will be less than double at the second stage also. In addition to the point on the voltage wave at which reclosure takes place, the value depends upon the line length and the angle between the voltages at the two ends of the line in accordance with Figure 8.

TRIPLE-POLE RECLOSING—DOUBLE-CIRCUIT TRANSMISSION LINE

Figure 10*A* represents a double-circuit transmission line with both circuits mounted on the same towers and with each circuit protected by its own reclosing circuit breaker. When a fault occurs on one circuit, only the circuit breaker on that circuit will open. The capacitive coupling between the isolated line and the energized line causes the isolated conductors to float at some intermediate voltage. This voltage, if high enough, will feed current through the flashover path as long as it is still partially ionized. If the voltage and current are small enough, this capacitive follow arc will interrupt itself as the ionized flashover path cools. On the other hand, if this capacitive coupling arc is supplied by a high enough voltage and current, it will represent a stable arcing condition and would arc indefinitely so that the circuit can never be successfully reclosed.

Figure 7A. Single-circuit transmission line equipped with triple-pole circuit breakers having shunting resistors with insulator flashover on phase 3

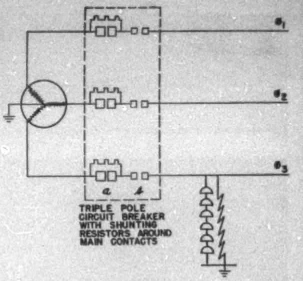
φ1
φ2
φ3
a
b
TRIPLE POLE CIRCUIT BREAKER WITH SHUNTING RESISTORS AROUND MAIN CONTACTS

Figure 7B. High-power laboratory circuit used to simulate reclosing with various de-energization times after interruption of fault current and 5-cycle resistor follow-current

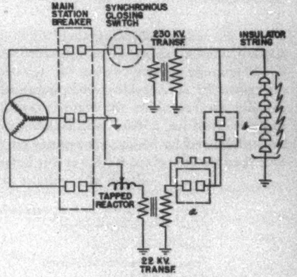

Figure 8. Maximum overvoltage oscillation on various lengths of 230-kv transmission line when reclosed at crest voltage by a circuit breaker equipped with shunting resistors of 2,700 ohms per pole

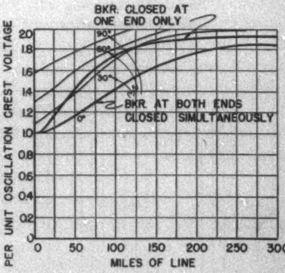

Figure 10*B* shows the test circuit used to simulate the capacitive coupling conditions to determine the length of time required for final interruption of this capacitive arc. The voltage at which the unenergized conductors tend to float is determined by the ratio of the circuit-to-circuit capacitance to the circuit-to-ground capacitance. The current which will flow is determined by the values of the capacitances. These tests showed that capacitive currents were interrupted successfully in two cycles or less as long as the coupling voltage did not exceed 10 kv with short initial short-circuit durations. Considerable randomness was encountered in the length of time required for interruption, but this is to be expected in such a nonstable arc. The magnitude of the coupling voltage appeared to be much more important than the current in the arc, for 5-ampere arcs required as long to interrupt as 50-ampere arcs.

Fortunately, capacitive coupling voltages at which one circuit of a double-circuit transmission line tends to float with normal transposition are appreciably below 10 kv.

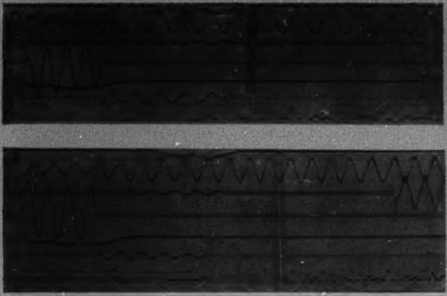

Figure 9. (A, top) Oscillogram of 8,000-ampere flashover test on 230-kv suspension insulator interrupted in 3.9 cycles followed by 50-ampere resistor current for 4.7 cycles—insulator then de-energized for seven cycles before being reclosed at a voltage crest causing arc reignition (B, bottom) Oscillogram of 8,000-ampere flashover test on 230-kv suspension insulator interrupted in 3.5 cycles followed by 50-ampere resistor current for 5 cycles—insulator then de-energized for 8.3 cycles before being successfully reclosed at a voltage crest

Trace 1—Trip coil current, auxiliary circuit breaker
Trace 2—Generator voltage
Trace 3—Arc voltage
Trace 4—Short-circuit current
Trace 5—Trip-coil current, main breaker
Trace 6—Resistor current
Trace 7—Circuit breaker travel

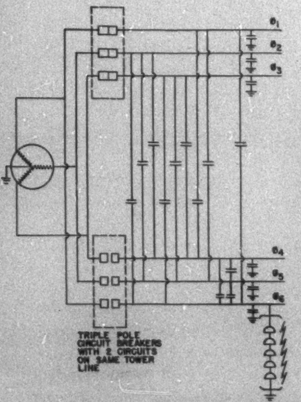
e1
e2
e3
e4
e5
e6
TRIPLE POLE CIRCUIT BREAKERS WITH 2 CIRCUITS ON SAME TOWER LINE

Figure 10A. Double-circuit transmission line with both circuits mounted on the same towers and with each circuit protected by its own triple-pole high-speed reclosing circuit breaker with insulator flashover on phase 6

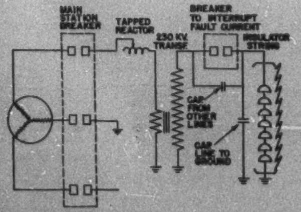

Figure 10B. High-power laboratory circuit used to determine the length of time required for interruption of capacitive follow-current with various values of capacitive-coupling voltage tending to sustain arc

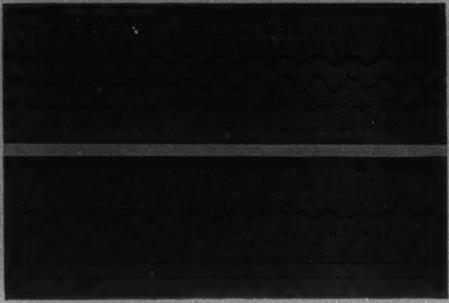

Figure 11. Continuous oscillogram of 7,100-ampere flashover on 230-kv suspension insulator interrupted in three cycles with capacitive-coupling voltage of 22 kv—capacitance current from 4.5 microfarads coupling representing 300 miles of line is not interrupted in 22 cycles

Trace 1—Trip-coil current
Trace 2—Generator voltage
Trace 3—Capacitor current
Trace 4—Arc voltage
Trace 5—Short-circuit current
Trace 6—Circuit-breaker travel

Therefore, the follow current generally will not continue for more than one or two cycles, and triple-pole reclosing may be used by allowing one or two cycles extra time in reclosing. In single-pole reclosing the two conductors remaining energized induce on the disconnected conductor, a substantially higher voltage, 22 kv for a particular 220-kv line with flat vertical spacing and ground wires. At this voltage, the duration of the capacitive current was found to vary from 18 to more than 30 cycles, when it was cleared by back-up protection. Single-pole reclosing for such a line would, therefore, not be successful except with extremely long de-energized times.

These conclusions may be drawn from this investigation:

1. When capacitive coupling is not present, the de-energization time after insulator flashover necessary to prevent arc reignition upon reclosure of the line increases linearly with the fault current on 230-kv systems, is practically constant for 132-kv systems, and decreases at high current on 69-kv systems. By adding the circuit-breaker interrupting time to the data obtainable from these figures, the minimum reclosing times permissible may be obtained.

2. On systems with small stability margins, gains in the maximum power transmission without loss of synchronism during transient faults may be obtained by using circuit breakers with reclosing time much less than the present standard of 20 cycles.

3. Triple-pole reclosing on double-circuit transmission lines may be accomplished by adding one or two cycles extra de-energized time. This will still fall well under the present standard of 20 cycles.

4. Shunting resistors do not tend to increase the minimum total reclosing time on circuit breakers applied on short lines. On long lines they may increase it up to the duration of the resistor follow current.

5. The capacitive coupling associated with single-pole reclosing appears to make single-pole reclosing infeasible under many conditions unless excessive de-energization times are allowed.

REFERENCE

1. Ultrahigh-Speed Reclosing of High-Voltage Transmission Lines, Philip Sporn, D. C. Prince. *Electrical Engineering* (*AIEE Transactions*), volume 56, January 1937, pages 81–90.

Dynamoelectric Amplifier—Class A Operation

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THE CHARACTERISTICS of dynamoelectric amplifiers operating under transient conditions have been discussed previously. This article points out the similarity of the external effects of these amplifiers to one another, shows their similarity to electronic amplifiers, and presents the equivalent circuits that can be used to predict satisfactorily the performance of these amplifiers under a-c steady-state conditions.

The American Standards Association definition of an amplifier is ". . . a device for increasing the power associated with a phenomenon without appreciably altering its quality, through control by the amplifier input of a larger amount of power supplied by a local source to the amplifier output." There are several rotating machines that can qualify as amplifiers under the foregoing definition; those considered in this article are the separately excited d-c generator, the Amplidyne, the Rototrol, and the Regulex. In each of these a large amount of output power can be controlled by a small control field current.

Considering first the separately excited d-c generator, the amplification will be distortionless (class *A*) at no load if the amplitude of the field current wave is such that operation is confined to the straight-line portion of the saturation curve. The d-c generator as a dynamoelectric amplifier is analogous to the electronic amplifier except that the power supplied is mechanical instead of electric; there is no direct current present in the output circuit; control is effected by a current instead of a voltage; and the control circuits contain inductance rather than capacitance. As a result of these differences, the d-c machine's frequency response extends to zero frequency (direct current) but the high-frequency cut-off is limited normally to relatively low frequencies, approximately 0.5 cycle per second or less in the d-c machine because of the high inductance of the control field.

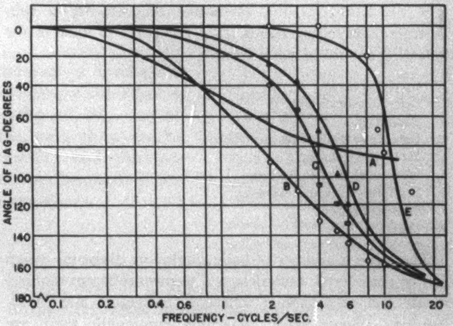

Figure 2. Phase angle characteristics of dynamoelectric amplifiers

A—Single stage, no feedback; B—two stage, no feedback; C—two stage, 10 per cent feedback; D—two stage, 20 per cent feedback; E—two stage, 100 per cent feedback

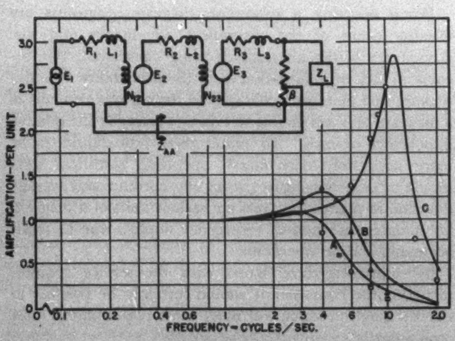

Figure 1. Frequency response characteristics of dynamoelectric amplifiers

A—Two stage, 10 per cent feedback; B—two stage, 20 per cent feedback; C—two stage, 100 per cent feedback. The circuit employed in calculating the results is shown

When making an analysis from the a-c steady-state point of view, one is concerned with the amplifications, the frequency-response characteristics, and zones of stability. To consider the dynamic characteristics an equivalent circuit is used and the response of the equivalent circuit to various frequencies is explored.

In the analysis several assumptions must be made.

1. The prime mover speed is constant.
2. Only the straight-line portion of the saturation curve is used.
3. The residual effects are negligible.
4. The hysteresis effects are negligible.
5. The parameters are linear.

Using the equivalent circuits and these assumptions, voltage amplification and phase angle characteristics can be computed. Very close agreement with test data results from these calculations, thus demonstrating the validity of the assumptions. Figure 1 shows a set of frequency-response characteristics for various degrees of negative feedback; Figure 2 describes the phase-angle characteristics. While these response curves are plotted in the customary fashion (that is, with 100 per cent for the zero-frequency point of all curves), it must be remembered that the power amplification is seriously impaired when feedback is used.

Digest of paper 49-295, "The Dynamoelectric Amplifier—Class A Operation," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Basic Single-Line Diagrams for Substations

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IN SELECTING the single-line diagram for a substation its requirements from the point of view of the following should be considered.

1. Service security.
2. Operating flexibility.
3. Simplicity.
4. Limitation of short-circuit current.
5. Protective relaying.
6. Maintenance of equipment.
7. Feasibility of future extension.
8. Standardization.
9. Cost.

There are a number of basic single-line diagrams which can be considered, each designed to meet different requirements and each having inherent advantages and disadvantages. Some basic diagrams commonly used are shown in Figure 1 and are described here briefly.

Single-bus diagrams (Figures 1*A*, 1*B*, and 1*C*). This diagram results in an inexpensive design but provides low degrees of service security and operating flexibility due to

1. Inadequate switching (lack of circuit breakers).
2. Nonduplication of elements (only one bus).

By progressively replacing the disconnecting switches by circuit breakers as shown in Figures 1*A*, 1*B*, and 1*C* improved service can be provided.

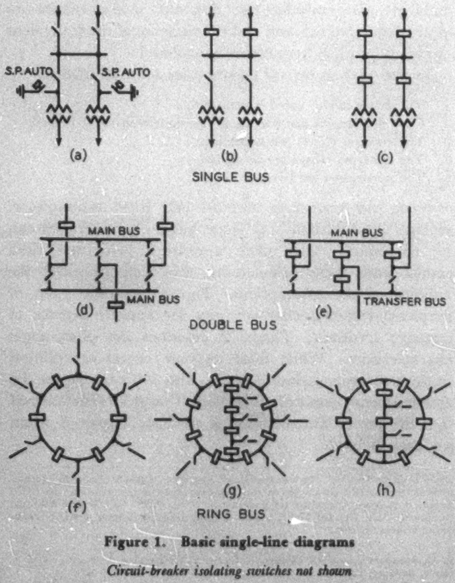

Figure 1. Basic single-line diagrams

Circuit-breaker isolating switches not shown

Double-bus diagrams (Figures 1*D*, and 1*E*). The double-bus diagram shown in Figure 1*D* is simple, flexible, and especially adaptable to substations where it is necessary to subdivide the elements into groups. It has the weakness that an element must be removed from service to maintain its circuit breaker, but this is not serious for many loads, particularly those having duplicate supplies.

In the main-and-transfer-bus diagram shown in Figure 1*E* all elements normally are connected to the main bus, the transfer bus being used to facilitate circuit-breaker maintenance without removing an element from service and for special system operating setups. By increasing the number of circuit breakers, with a corresponding increase in cost, greater service security and flexibility can be obtained, the maximum being obtained when two circuit breakers per element are used.

Ring-bus diagrams (Figures 1*F*, 1*G*, and 1*H*). The main advantages of the ring bus are that it needs few circuit breakers, it can be relayed with simple zone relay schemes, and it is possible to maintain circuit breakers without removing elements from service. Its main disadvantages are that its operating flexibility is limited in so far as subdividing the elements into groups is concerned and it provides low security when a circuit breaker is out of service.

The simple ring-bus diagram shown in Figure 1*F*, can be used to accommodate any number of elements, but to ensure good service the number of elements is usually limited to six. For stations having more elements or requiring a higher standard of service the $1^{1}/_{2}$-circuit-breakers-per-element, or the $1^{1}/_{2}$-circuit-breakers-per-element diagrams shown in Figures 1*G* and 1*H*, or variants of these are often used.

When selecting a substation diagram, engineers are usually aware of the theoretical advantages and disadvantages of the alternatives being considered, but because of lack of information as to the probability of maintenance and emergency outages on the various elements of a diagram they are unable to evaluate correctly the relative importance of each. To enable these probabilities to be more accurately determined, operating statistical data should be kept showing frequency of occurrence and average duration of planned outages on various units of a diagram for maintenance and of emergency outages due to faults occurring during operation.

By comparing these figures with the service requirements of the consumer it should certainly be possible to select a diagram which will meet these requirements most economically.

Digest of paper 49-285, "Basic Single-Line Diagrams for Substations" recommended by the AIEE Committee on Substations and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Not scheduled for publication in AIEE *Transactions*.

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Analysis of Transients and Feedback in Magnetic Amplifiers

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The steady-state characteristics of a saturable reactor can be used to determine the effect of feedback on the properties of the reactor. This article discusses the equivalent control circuits for saturable reactors and develops formulas for computing the performance of certain magnetic amplifiers.

THE TERMS saturable reactor, d-c controllable reactor, transductor, and magnetic amplifier have been used to denote an iron-cored inductor in which the a-c impedance can be controlled by magnetically saturating the core with an auxiliary d-c winding. In this article, the term saturable reactor will be used to denote the iron-cored inductor itself, and the term magnetic amplifier will be applied to the entire circuit which makes use of the properties of the saturable reactor in order to amplify a signal. In many practical magnetic amplifiers, positive feedback is used to increase the amplification.

The steady-state characteristics of the saturable reactor have been discussed in many papers, and its properties have been related to the nonlinear characteristics of the core in a number of different ways by different investigators.[1–5] The purpose of this article is to show how the steady-state characteristics of the saturable reactor, whether computed or determined experimentally, can be used to determine the effect of feedback on both the steady-state and the transient properties of the device. The illustrative computations given in this article are based on the steady-state analysis given in reference 1, but the general methods can be applied equally well to the steady-state characteristics as found by any other means, including experimental methods.

THE STEADY-STATE LOAD LINE

A useful method of presenting the characteristics of a saturable reactor is to plot a family of curves of rms voltage across the reactor terminals versus either the rms or the average current through the reactor, one curve for each of a number of values of control current. An example of this is shown in Figure 1 for a commercial saturable reactor with a 4-legged silicon-steel core. This particular reactor was chosen for a number of these experiments because its comparatively large current-handling capacity facilitated accurate measurements of current and voltage. The quantity labeled I_m on the graphs is the net d-c magnetizing current referred to the control winding. For steady-state operation without feedback, this is equal to the control-winding current. The advantage of the type of presentation shown in Figure 1 is that it is not restricted to any particular value of supply voltage or to any particular value or type of load impedance. However, these graphs must be measured or computed on the basis of a particular wave shape of applied voltage, usually a sinusoidal one. The question is whether, because of the nonlinearity of the device, the curves so obtained can be applied to the operation of the reactor when connected to a load, for here the reactor voltage will not be sinusoidal.

When a saturable reactor is connected in series with a load impedance as shown in Figure 2, the load current will be small when the reactor is unsaturated. Then the voltage drop across the load will be small, and the reactor voltage will be nearly sinusoidal. On the other hand, when the reactor is saturated, the load current and load voltage will be large, and the reactor voltage will be nonsinusoidal. However, it has been shown previously[6] that, under the saturated condition, the characteristic curves of the reactor are affected only a little by the wave shape of the terminal voltage. Hence, we may expect that the characteristic curves will apply reasonably well to the loaded condition, and that a load line based on linear circuit theory can be traced on the characteristics of the

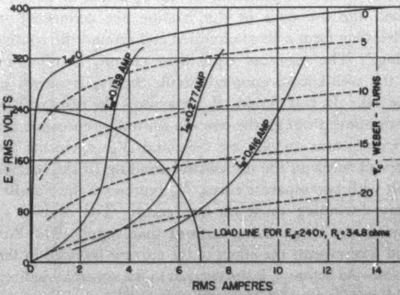

Figure 1. A characteristic family of curves for a commercial saturable reactor (*66G912*) with a 4-legged silicon-steel core. These give the rms voltage across the reactor terminals versus the current through the reactor for a number of values of net d-c demagnetizing current referred to the control winding

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Essentially full text of paper 50-94, "An Analysis of Transients and Feedback in Magnetic Amplifiers," recommended by the AIEE Committee on Electronics and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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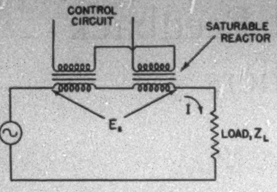


Figure 2. The saturable reactor connected in series with a load impedance

reactor. The foregoing conclusion has been checked experimentally for various load lines on different reactors, and the results have been found to be uniformly satisfactory.

If the load impedance shown in Figure 2 is a resistance, and if the reactor is temporarily considered as a linear inductance, the relationship between the reactor voltage and the rms current is the ellipse

$$\left(\frac{E_s}{E_a}\right)^2+\left(\frac{I}{E_a/R_L}\right)^2=1 \tag{1}$$

where E_s is the rms voltage across the saturable reactor; E_a is the rms applied voltage; I is the rms current in the circuit, and R_L is the load resistance.

Thus, the load line is an ellipse with the intercepts E_a and E_a/R_L, as shown in Figure 3. The load line for a purely inductive load would be a straight line connecting the intercepts E_a and E_a/X_L, where X_L is the reactance of the load.

TRANSIENT OPERATION WITHOUT FEEDBACK

Equivalent Control Circuit. When the a-c coils of the saturable reactor are connected in series, as shown in Figure 2, a change in the flux that links the control circuit will induce equal and opposite voltages in the two a-c coils, and these coils are therefore open-circuited in so far as changes in the control circuit are concerned. The equivalent control circuit for this condition is shown in Figure 4*A*, in which i_c represents the current in the control winding and ψ_c represents the flux linkage of this winding. The current in the control winding is here the only current that produces a d-c magnetomotive force, and so it is equivalent to the magnetizing current I_m of Figure 1.

When the a-c coils of the reactor are connected in parallel, they form a short-circuited coil around the control winding.[7] The resulting equivalent circuit, as obtained from the well-known coupled-circuit theory, is shown in Figure 4*B*. In this circuit, R_{ac} represents the resistance of the series path through the two a-c coils, N_{ac} represents the number of turns on one a-c coil, and N_{dc} represents the number of turns on the d-c control winding (if the reactor is built with two separate cores, N_{dc} represents the number of control-winding turns on one core). The current i_m represents the magnetizing current that supplies the flux ψ_c, and i_t represents the effect of the current induced in the a-c coils. As before, i_c is the current in the control winding, but this now is equal to the sum of i_m and i_t.

Figure 4*C* shows the equivalent circuit for parallel-connected a-c coils, reduced to a more convenient form by Thévenin's theorem. The time lag introduced by the leakage fluxes is generally much smaller than that caused by the main control flux, ψ_c, and so, for simplicity, the leakage inductances have been neglected in the last diagram. The effective resistance for transient changes in i_m is the parallel combination of R_c and R_{ac}'.

Control-Circuit Flux Linkage. The transients caused by changes in the system will depend on the relation between the control-winding flux linkage, ψ_c, and the magnetizing current i_m. The main time lag is caused by the slowness of change of the flux that links the control winding, and so we shall assume that the steady-state load line is followed during transient conditions. The flux linkages of the control winding, as computed by the method of reference 1, are shown as dashed curves in Figure 1. By following along the load line, one can plot the relation between the magnetizing current and the flux linkage of the control circuit. This plot is shown in Figure 5 for the load line of Figure 1.

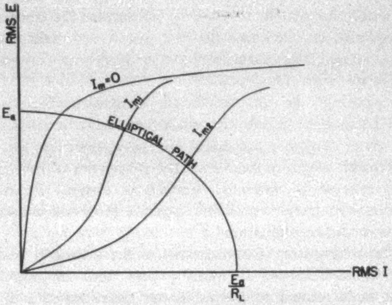


Figure 3. The elliptical path is the load line for the circuit of Figure 2 when the load, Z_L, is purely resistive

The foregoing graph of ψ_c versus i_m was drawn for a given load line. If a transient is caused by a sudden shift from one load line to another (change in applied voltage or in load impedance), the transition will take place along a line of constant ψ_c in Figure 1; this will determine the initial condition for the transient.

Transient Response. If the changes that take place are small enough in magnitude so that they traverse only a substantially linear segment of the control-circuit magnetization curve, the transient will be nearly exponential and a time constant can be defined. The average slope of the magnetization curve between the two points in question, expressed in weber-turns per ampere, is the effective inductance of the control winding, L_c henrys. The effective time constant is then L_c/R henrys, where R is the effective resistance of the control circuit as obtained from the appropriate equivalent circuit of Figure 4. For example, at a current of 0.2 ampere in Figure 5, the slope of the graph is approximately 41 weber-turns per ampere; that is, the effective inductance in the control circuit is 41 henrys. The effective resistance in the control circuit then determines the time constant. It will be observed in Figure 4 that, with series a-c coils, the time constant can be decreased indefinitely by increasing the resistance of the control circuit, R_c. But, with the a-c coils in parallel, the effective resistance for the transient is composed of R_c in parallel with R_{ac}', and so there is a lower limit for the time constant which is determined by R_{ac}'.

When the change in control current is so large that it involves considerable curvature in the characteristics, the transient will not be exponential and the concept of a time constant loses much of its usefulness. In spite of this, it may sometimes be useful to estimate a mean value for the inductance and compute an approximate time constant. If more accurate results are desired, they can be obtained with a step-by-step integration of the magnetizing-current transient.

STEADY-STATE OPERATION WITH FEEDBACK

Feedback circuits for the magnetic amplifier exist in great variety. Basically, the a-c load current is rectified and is applied to the magnetic core in such a way as to aid the saturation that is produced by the control current; in this way the steady-state amplification can be increased to the point of instability. Figure 6*A* shows a magnetic amplifier with external feedback; that is, the feedback winding is separate from the load-current winding. Other magnetic amplifiers use self-feedback in which one set of windings serve as both load-current and feedback windings. One of these circuits is shown in Figure 6*B*. Since it is the average value of the rectified load current that is effective in feedback, the subsequent discussion will be based on the average-current characteristic curves of the saturable reactor.

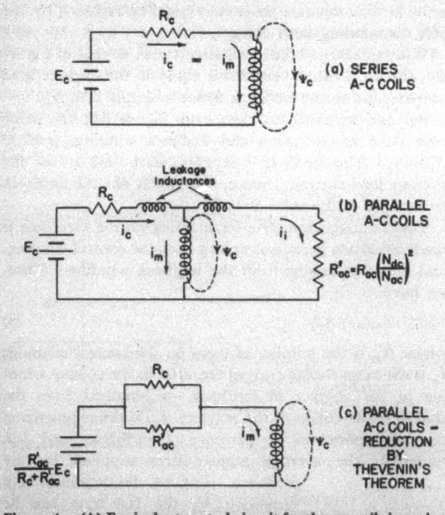


Figure 4. (A) Equivalent control circuit for the a-c coils in series; (B) equivalent control circuit when the a-c coils of the reactor are connected in parallel so they form a short-circuited coil around the control winding; (C) the equivalent circuit for parallel-connected a-c coils reduced by Thêvenin's theorem with leakage inductances neglected

A set of average-current curves for reactor *66G912*, as computed by the methods of reference 1, are shown in Figure 7. The values of I_m on the curves are shown with ± signs because the reactor element without feedback cannot distinguish between the two directions of control current.

Load Line on an Average-Current Basis. If dry-plate rectifiers are used in the feedback circuit, their characteristics can be approximated by a constant resistance in the forward direction. If this resistance is added to that of the load itself, the intercepts of the load line can be found as for the rms-current case (Figure 3) except that the intercept on the current axis is replaced by

$$\frac{E_a}{1.11\,R_L}\text{ average amperes}$$

where R_L is the apparent load resistance including the forward resistance of the rectifiers.

When gas-tube rectifiers are used, the voltage drop across each tube is nearly constant during conduction, and this introduces a further non-linearity into the analysis. Reasonable results are obtained by determining the intercepts of the load line as follows:

$$\text{Voltage intercept} = E_a - V_t \qquad (2)$$

where V_t is the tube drop through the rectifier tubes that are instantaneously in series with the load (two tubes in Figure 6*A*; one tube in Figure 6*B*).

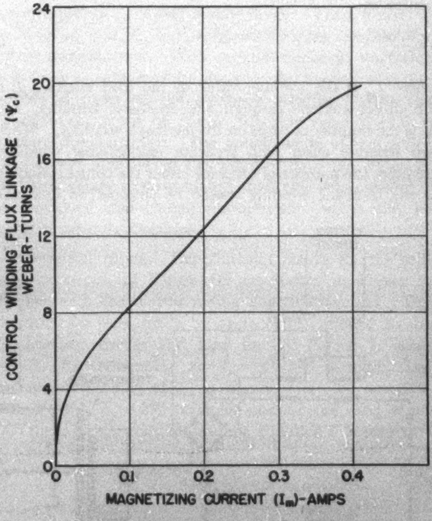


Figure 5. Magnetization current versus flux linkage of the control circuit (Figure 4) for the load line of Figure 1

From this magnetization curve the effective time constant can be obtained

$$\text{Average-current intercept} = \frac{E_a/1.11 - V_t}{R_L} \tag{3}$$

where R_L is the resistance of the load.

The load path then can be drawn as an ellipse between these intercepts. In the external-feedback circuit of Figure 6*A*, the a-c coils can be connected either in series, as shown, or in parallel. The load line is then drawn on the appropriate characteristic curves. In the self-feedback circuit of Figure 6*B*, the appropriate average-current curves are essentially the same as those of the parallel-connected reactor. (Note, however, that there is no path for an induced circulating transient current, and so the equivalent circuit of Figure 4*A* is applicable for transients.)

Effect of Feedback on Control Current. The effect of feedback will be expressed in terms of a feedback factor β which will be based on the magnetizing ampere-turns that act on one core of a 2-core unit, or on one a-c flux path of a 3- or 4-legged single-core unit. It will be defined as the ratio between the d-c feedback ampere-turns and the average a-c ampere-turns and will normally range between zero and unity.

It will be convenient to base the formula for β on the total number of a-c turns in series between the a-c terminals of the complete reactor N_{ac}. This will be equal to twice the number of turns on one a-c coil for the series coil connection and will be equal to the number of turns on one coil for the parallel connection.

If the a-c coils are connected in series, the number of a-c turns on one core will be $N_{ac}/2$. On the other hand, with a parallel connection, only half the average load current will flow through each coil.

Hence, for either connection, the feedback factor can be written as

$$\beta = \frac{2N_f I_f}{I_{av} N_{ac}} \tag{4}$$

where I_{av} is the average value of the load current, I_f is the direct current through the feedback winding, and N_f is the number of turns on the feedback winding. When two separate cores with separate magnetizing windings are used, the number of turns for either the control winding or the feedback winding should be counted on one core only, for two separate series coils could be replaced by one coil surrounding both cores.

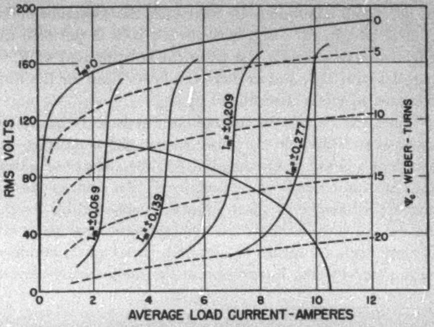


Figure 7. A characteristic family of curves for a commercial saturable reactor (*66G912*) on an average-current basis with the a-c coils connected in parallel; I_m is shown ± because the direction of control current has no effect on a reactor without feedback

With an external feedback circuit such as that of Figure 6*A*, the d-c feedback current is equal to the average load current, and so the feedback factor is simply $2N_f/N_{ac}$.

For the self-feedback circuit of Figure 6*B*, the same coils serve as both load and feedback windings, and so $N_{ac} = N_f$. The feedback current in each coil is half the average load current; hence, this circuit has the feedback factor fixed at the value $\beta = 1.0$.

The d-c magnetomotive force acting on the core now is made up of two parts, one arising from the control winding, and the other arising from the feedback winding. Thus, we have

$$N_{dc} I_m = N_{dc} I_{mf} + N_f I_f \tag{5}$$

where N_{dc} is the number of turns on the control winding; I_m is the magnetizing current required in the control winding in the absence of feedback, as obtained from the characteristic curves of the reactor; I_{mf} is the magnetizing current required in the presence of feedback; and $N_f I_f$ represents the average ampere-turns supplied by the feedback. But, by the definition of β (equation 4), the last term can be replaced by $\beta I_{av} N_{ac}/2$, and so equation 5 can be written

$$I_{mf} = I_m - \frac{\beta I_{av} N_{ac}}{2N_{dc}} \tag{6}$$

This equation can be used to compute the control current required to produce any given value of I_{av} along the load line. It was noted that the reactor

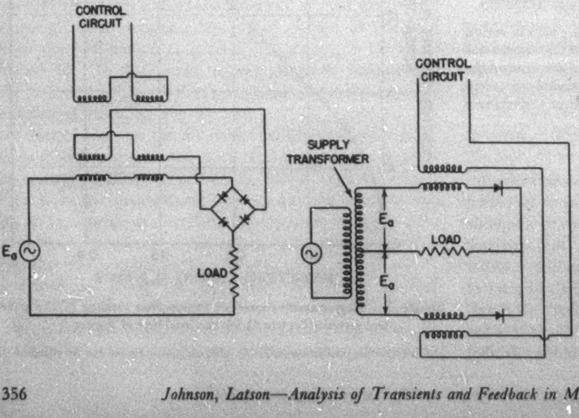


Figure 6. (A, left) Magnetic amplifier with external feedback—the feedback winding is separate from the load-current winding; (B, right) magnetic amplifier with self-feedback in which one set of windings serve both as load-current and feedback windings

without feedback cannot distinguish between the two directions of control current, and that the values of I_m assigned to the curves of Figure 7 can therefore be taken to be either positive or negative currents. For a given value of I_{av}, this produces two different values of I_{mf} from equation 6. The positive value of I_m corresponds to positive feedback; the negative value to negative feedback.

The variation of control current along any given load line, and the effect of different load lines, can be visualized in Figure 8. Equation 6 can be written in the form

$$\alpha I_{mf}=\alpha I_m-I_{av} \tag{7}$$

where $\alpha=2\ N_{dc}/\beta N_{ac}$. Figure 8*A* shows one of the characteristic curves of the reactor for a constant value of I_m. The intersection of this curve with the load line (point *A*) determines a value of I_{av} as shown. To find the corresponding value of control current, two lines are drawn on opposite sides of the vertical axis, each located αI_m units away as measured on the horizontal current scale. Then, as shown by equation 7, either of the lines *A-B* or *A-C* represents a value of αI_{mf} that will produce steady-state operation at point *A* on the load line. Both of these currents are shown negative in the drawing. Figure 8*B* shows a complete family of characteristic curves, and the horizontal arrows indicate the required values of αI_{mf} at various points on the load line. With zero control current, the circuit comes into steady state at the quiescent point where αI_{m_2} intersects the curve for I_{m_2} on the load line. This construction makes the effect of varying the load line especially easy to visualize.

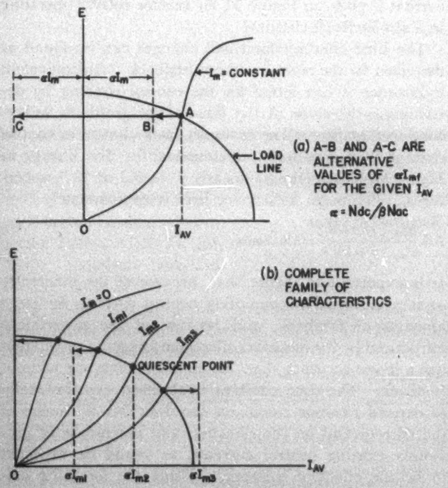

E
αIm
αIm
Im = CONSTANT
A
C
B
LOAD LINE
O
IAV
(a) A-B AND A-C ARE ALTERNATIVE VALUES OF αImf FOR THE GIVEN IAV
α = Ndc/βNac
E
(b) COMPLETE FAMILY OF CHARACTERISTICS
Im=0
Im1
Im2
Im3
QUIESCENT POINT
O
αIm1
αIm2
αIm3
IAV

Figure 8. Graphical construction for determining control current with feedback present

A—Lines A-B and A-C represent values of αI_{mf} that give steady-state operation point A on the load line

B—Complete family of characteristic curves; the horizontal arrows show the required values of αI_{mf} at various points on the load line

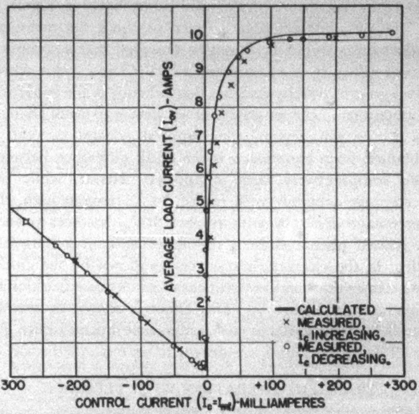


Figure 9. Experimental points check closely with the steady-state control characteristic for reactor *66G912* in a self-feedback circuit

The construction of Figure 8 shows clearly the requirement for a high amplification: namely, that αI_m shall be approximately equal to I_{av} over a large portion of the load line. This requires the proper choice of α and also requires that the intersections of the characteristic curves with the load line should come at approximately equal intervals along the abscissae. The universal curves of reference 1 show that, if a saturable reactor has only a small air-gap line, the quantity I_mN_{dc}/N_{ac} is approximately equal to $I_{av}/2$ over a wide range. Then, if $\beta=1.0$, we have $\alpha I_m=2I_mN_{dc}/\beta N_{ac}\approx I_{av}$, which is the condition for a large amplification. With external feedback, this value of β must be obtained by an accurate control over the number of turns on the feedback winding. With the self-feedback circuit of Figure 6*B*, the value $\beta=1.0$ is obtained automatically. The amplification of the device will be very sensitive to the value of β in the region of 1.0,[8] and values slightly higher than this will produce a double-valued load-current characteristic (which may be useful in some applications).

Experimental Results. Experimental results for the self-feedback circuit of Figure 6*B* are shown in Figure 9, together with the corresponding computed values. The computations were made by applying equation 6 to the characteristic curves and load line of Figure 7, using $\beta=1.0$. For example, at $I_m=\pm0.277$ ampere, the corresponding value of I_{av} in Figure 7 is 8.80 amperes. With $\beta=1.0$, $N_{ac}=230$ turns for one a-c coil, and $N_{dc}=4000$ turns on the control winding, equation 6 becomes

$$I_{mf}=\pm0.277-0.500\times8.80\times\frac{230}{4{,}000}$$

$$=\pm0.277-0.253$$

$$=0.024 \text{ ampere or } -0.530 \text{ ampere}$$

These values, together with the value $I_{av}=8.80$ amperes, determine two points on the solid curve shown in Figure 9.

The calculated results are seen to check the measured values quite well. It should be observed that a computational difficulty is encountered when β has a value which gives great sensitivity and that this difficulty is the analytical counterpart of the sensitivity of the device to small changes in β. In this region, the required control current as obtained from equation 6 is the small difference between two comparatively large quantities. Hence, while the percentage accuracy with respect to I_m remains high, the percentage accuracy with respect to I_{mf} becomes poorer. A related phenomenon is the appearance of a hysteresis effect in the characteristic curves as shown by the circles and crosses that mark experimental points taken in different directions in Figure 9. This effect is shown in greater detail by Figure 10, in which the experimental data for small control currents are drawn to an expanded scale.

TRANSIENT OPERATION WITH FEEDBACK

A given change in load current along a given load path corresponds to the same change in d-c flux regardless of the amount of feedback. For small changes in load current, the effective inductance of the control winding is

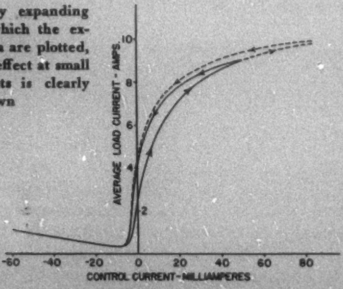
$$L=\frac{\Delta\psi_c}{\Delta i_{mf}} \qquad (8)$$

where $\Delta\psi_c$ is the change in the control-winding flux linkage, and Δi_{mf} is the corresponding change in magnetizing current with feedback. The application of feedback reduces Δi_{mf} for a given $\Delta\psi_c$, and so increases the inductance seen by the control circuit. If the same resistance is maintained in the control circuit after feedback is applied, the time constant L/R_c will be increased proportionately to the amount that the sensitivity of the amplifier is increased. To keep the time constant the same after feedback is introduced, the control-circuit resistance must be increased. The effect can be shown as follows:

$$\text{Time constant, } t_c=\frac{L}{R_c}=\frac{\Delta\psi_c}{R_c\Delta i_{mf}}=\frac{\Delta\psi_c}{\Delta e_c} \qquad (9)$$

For small changes along any given part of the load path, the time constant varies inversely with the required increment in control-circuit voltage, Δe_c. If R_c is increased in the same proportion as Δi_{mf} is reduced, both Δe_c and the time constant will remain constant. The sensitivity to changes in control current now is greater than without feedback, but the sensitivity to changes in control voltage is the same as before.

Figure 10. By expanding the scale on which the experimental data are plotted, the hysteresis effect at small control currents is clearly shown



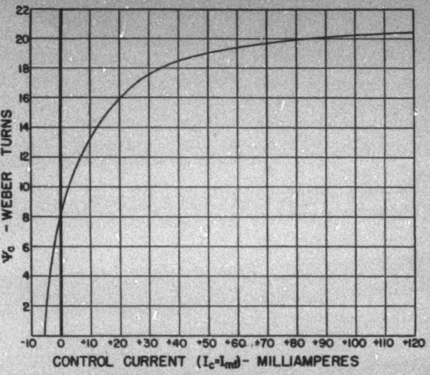


Figure 11. Magnetization current versus flux linkage of the control circuit with reactor *66G912* in a self-feedback circuit

Analysis. The computation of transients in the feedback amplifier follows the same principles outlined earlier for the magnetic amplifier without feedback. The only difference is that the feedback changes the control current for a given control-winding flux linkage so that Figure 5 no longer applies. A graph of flux linkage versus control current is given in Figure 11 for reactor *66G912* operating in a self-feedback circuit.

The time constant for small changes can be found as described for the reactor without feedback. An equivalent inductance is first found for the control winding by determining the slope of the flux-linkage graph in weber-turns per ampere. For example, for a change in control current from zero to 9 milliamperes, the flux linkage in Figure 9 changes almost linearly from 8.2 to 12.9 weber-turns. The mean inductance here is approximately

$$L\approx\frac{\Delta\psi_c}{\Delta i_{mf}}=\frac{12.9-8.2}{9\times10^{-3}}\approx520 \text{ henrys}$$

It is important to realize that, because of the inherently smaller accuracy in computing control currents for large amounts of feedback, and because of the uncertainty introduced by the hysteresis effect, the foregoing calculation has a lower accuracy than the corresponding one without feedback. The time constant is observed experimentally to depend to some extent on the direction of change of the current and on the direction and magnitude of previously existing control currents, as would be expected to be the effect of hysteresis. Using the foregoing calculated value of inductance, a resistance of 139 ohms in the control circuit would produce a time constant of $L/R_c=520/139\approx3.7$ seconds in the region between zero and 9 milliamperes control current. An oscillogram of a transient between these two points showed an approximately exponential variation which had a time constant of about

3.3 seconds. This result, with the calculated value 12 per cent higher than the measured value, is typical of the time constants that have been checked. The error has generally been of the order of 10 or 15 per cent, with the calculated result being high. It should be emphasized that the foregoing results were computed by starting with the a-c saturation curve of the core, and that no experimental corrections were used at any stage of calculations.

If desired, the path of a transient that spans a markedly nonlinear portion of the flux-versus-current graph can be computed graphically by a step-by-step method. The main error here is caused by the uncertainty introduced into the initial condition by the hysteresis effect.

If a comparatively large control voltage is used to force the control current to change rapidly to a point well above the knee of the control-circuit magnetization curve, the $i_m R_c$ drop can be neglected during most of the change in flux, and the time required for the flux linkages to change an amount $\Delta\psi_c$ is only slightly greater than $\Delta\psi_c/E_c$, where E_c is the suddenly-applied control voltage. For example, reactor *66G912* connected in the self-feedback circuit was started at $\psi_c=6$ weber-turns ($I_{av}=0.8$ ampere), and an electromotive force of 47 volts was suddenly applied to the control winding. This was sufficient to produce a steady-state control current of 300 milliamperes, which is well above the knee of the curve of Figure 11. The final value of ψ_c is, from Figure 11, about 21 weber-turns ($I_{av}=10.2$ amperes). Therefore, the approximate time of rise is $\Delta\psi_c/E_c=(21-6)/47=0.32$ second. An oscillogram showed that the load current rose almost linearly to 10 amperes in 0.31 second.

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New Lightning Arrester Standard

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A new Lightning Arrester Standard, a combination of three separate earlier AIEE Standards bearing on the lightning protective devices field, has been issued. In this Standard, number 28A, the material also has been revised somewhat to improve clarity of expression.

FOR THE PAST several years there have been three separate AIEE Standards bearing on the lightning Protective devices field: Report on Proposed Standard for Protector Tubes, AIEE 24, July 1940; American Standards for Lightning Arresters for A-C Power Circuits, AIEE 28, May 1944; and Proposed Standard for Expulsion Type Distribution Lightning Arresters, AIEE 47, December 1945; all prepared under the sponsorship of the AIEE Protective Devices Committee. By the time of the publication of AIEE Standard 47, it was evident that there was much material in these various Standards which had a common application, and many of the definitions and test procedures were common. W. J. Rudge, then Chairman of the Lightning Protective Devices Subcommittee of the Protective Devices Committee, perceived the advantages of merging all three Standards, and set up a working group for such a project.* It was believed that the combining of Standards on lightning protective devices not only should lead to improved nomenclature, but would bring into sharper focus the inherent characteristics of the different species of lightning arresters, and at the same time would improve the accessibility of desirable information.

Early in the course of the undertaking, the Working Group encountered a tendency to incorporate in the Standard material which was of considerable importance in the proper application of lightning arresters. After very careful consideration by the Lightning Protective Devices Subcommittee, it was the consensus of opinion that inasmuch as this material was concerned primarily with the nature

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Full text of paper **50-82,** "New Lightning Arrester Standard," recommended by the AIEE Committee on Protective Devices and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

H. R. Stewart is with the New England Power Service Company, Boston, Mass., and **F. M. Defandorf** is with the National Bureau of Standards, Washington, D. C.

*The new Standard covered by this article was prepared under the sponsorship of the AIEE Protective Devices Committee, G. B. Dodds, Chairman, and its Lightning Protective Devices Subcommittee consisting of H. A. Cornelius, F. M. Defandorf, R. H. Earle, Milan Getting, I. W. Gross, E. H. Grosser, H. W. Hartzell, T. H. Mawson, T. I. Eldridge, W. A. McMorris, A. M. Opsahl, W. E. Rushlow, A. H. Schirmer, J. M. Towner, E. R. Whitehead, E. H. Yonkers, and H. R. Stewart, Chairman. Membership of the working group has included: E. Beck, R. H. Earle, H. N. Ekvall, I. W. Gross, E. H. Grosser, D. D. MacCarthy, J. R. McFarlin, W. A. McMorris, A. M. Opsahl, W. J. Rudge, W. E. Rushlow, A. H. Schirmer, H. R. Stewart, J. M. Towner, H. B. Wolf, E. H. Yonkers, and F. M. Defandorf, Chairman.

of the associated circuits and lines, a separate project be set up to devise a suitable Application Guide for Lightning Arresters that would fulfill the needs of the user more completely than one could hope for by inclusion of a few precautionary suggestions in the Standard. Even with this desirable simplification, the working group of users' and manufacturers' engineers found a number of loose ends to tie together in their task of improving and combining earlier efforts into a single Standard.

A perusal of the definitions in the new "Lightning Arrester Standards for Valve and Expulsion Arresters," AIEE 28A, will show several differences adopted primarily to improve clarity and definiteness of expression. These new definitions have been correlated with the current revision being made in the American Standards Association Standard Definitions of Electrical Terms, C42.

It will be noted that the term "protector tube" has been superseded by "expulsion arrester" so that all devices covered by the new Standard are referred to as "arresters" of one type or another. Classifications such as "station type," "line type," "distribution type," and "secondary type" are not defined in the Standard, and it is left to the maker to apply such designations. However, the Standard does state the appropriate tests for arresters of these various classifications. Regarding discharge-current withstand tests (formerly called discharge capacity) of arresters and prorated sections, the requirements have been altered to bring them in line with tests that can be performed in existing laboratories. The formerly specified five-by-ten wave (with stated tolerances) has been changed to "a surge current with wave-front duration between five and ten microseconds and wave-tail between 10 and 20 microseconds" having crest ampere values of 100,000 for station arresters, 65,000 for line and distribution arresters, and 10,000 for secondary arresters, it being specified that tests shall be on complete arresters up to nine kilovolts or prorated characteristic elements whose ratings are three kilovolts or greater but need not exceed nine kilovolts. This restatement is in better accord with laboratory tests that can be made with existing surge-testing equipment.

With respect to duty cycle tests on expulsion arresters, it is recognized that the severity of the test is very dependent on the voltage recovery rate of the test circuit. However, with the past lack of knowledge of the range of recovery rates on the circuits on which these devices are used in service, particularly on distribution circuits, it has not been possible to include in the Standard any specified voltage-recovery voltage rates for the duty-cycle test circuit with any assurance that they would reflect conditions found in service. At the present time a joint working group of the Transmission and Distribution Committee and of the Lightning Protective Devices Subcommittee appointed to study rates of rise of recovery voltage on distribution systems has made considerable progress on this matter, both by field and laboratory tests. The results should prove valuable not only in the future revision of lightning arrester Standards, but also to standardizing groups interested in fuses and other distribution-type interrupting devices.

Similarly, it has not been possible to include in the new Standard any values for radio influence tests due to lack of knowledge of requirements and pending extensive work by various industry groups needed before Standards can be formulated. Note that for special arresters used for the protection of rotating machinery, the acceptance tests as to the current magnitude at which the discharge voltage test is made and the rate of rise of voltage for the impulse sparkover test are lower than those respectively required for Standard arresters. This is in recognition of the fact that these special arresters are usually applied in conjunction with wave-sloping capacitors which materially change service conditions under which the arresters must operate.

Table I of the Standard specifying withstand test values for the assembled insulation of lightning arresters represents a considerable change from the similar table in Standard 28. Whereas the earlier Standard stated that, "Where application is to be made of an arrester having a lower voltage rating than the rated voltage of the circuit on which it is to be used, such as on grounded-neutral circuits, the insulation test shall be that specified for the insulation class one step lower than the rated circuit voltage," the new Standard includes these intermediate ratings in the listed arrester voltage ratings and assigns to them withstand test values which are interpolated between withstand test voltages assigned to the formerly listed next higher and lower ratings, each of which corresponds to Standard basic insulation levels. No insulation classifications are assigned to these intermediate arrester ratings.

The inclusion of the intermediate arrester ratings in Table I in this manner is a compromise solution of a very difficult problem on which widely diverging views were held. One view was that whereas grounded-neutral circuits usually are built with full insulation, grounded-neutral arresters used on those circuits should also have full insulation rather than insulation conforming with one basic insulation level step lower. On the other hand, this might mean a redesign of some of the intermediate-voltage-rating arresters if they should conform to the basic insulation level of the full insulated circuit on which they are used. Since a general redesign of arresters may be imminent if the present deliberations of the Joint AIEE-Edison Electric Institute-National Electrical Manufacturers Association Committee on Insulation Co-ordination should result in a revision of present basic insulation levels, it did not seem wise to call for insulation values in the new Standard which would necessitate a possible interim redesign. It will be noted in view of this activity by the Joint Committee on Insulation Co-ordination that all values in Table I of the Standard are to be considered, as expressed in a footnote, as interim values subject to revision when the report of the Joint Committee is issued. Also, the addition of the intermediate arrester values to Table I should not be considered as a precedent for adding basic insulation levels to an existing Standard list on the part of groups standardizing tests on individual types of apparatus.

Like all other Standards, the "revised and combined" Lightning Arrester Standard is not presented as the last word but rather as a closer approximation to a desirable Standard. More information as to better tests for lightning arresters always will be needed and the Standard will continue to be improved as the result of improved tests.

Digests of Papers Presented at Electric Welding Conference

These are authors' digests of most of the papers to be presented at the Conference on Electric Welding, Detroit, Mich., April 5–7, 1950. The conference is sponsored by the AIEE in co-operation with the American Welding Society and the Industrial Electrical Engineers Society in Detroit. These papers are not scheduled for publication in AIEE Transactions or AIEE Proceedings, nor are they available from the Institute.

New Electrodes for Stabilizing Inert-Gas Welding Arcs; *J. D. Cobine, C. J. Gallagher* (*General Electric Research Laboratory, Schenectady, N. Y.*).

New welding electrodes have been developed which eliminate the erratic starting and the instability often observed with the usual pure tungsten electrode used in inert-gas welding. These new electrodes are intended primarily for straight polarity welding. Two forms have been developed. One consists of a pure tungsten rod, coated with either zirconia (ZrO_2) or thoria (ThO_2) and a suitable binder. The other consists of a mixture of tungsten and thoria powder extruded into rods and sintered. On application of high-frequency ignition voltage the arc is immediately established on the tip of the electrode, whereas with pure tungsten the starting may be delayed considerably, and the foot of the arc may wander rapidly over the whole electrode surface. These new electrodes have other advantages. They require open-circuit generator voltages much less than for tungsten. In addition, the current range for a given electrode size is greatly extended. For example, the normal range for 0.100-inch tungsten is about 140 to 280 amperes. For the sintered electrode of the same size, the range is 10 to 375 amperes. Material loss within the operating current range is slight.

The Electric Arc in Argon and Helium; *T. B. Jones, Merrill Skolnik* (*Johns Hopkins University, Baltimore, Md.*).

An investigation has been undertaken to determine the fundamental electrical properties of the d-c arc using electrodes of high melting point materials in an atmosphere of an inert gas. Rod electrodes were used, mounted coaxially, in an enclosed chamber which permitted careful control of experimental conditions. With pure argon or helium gas, at atmospheric pressure, the arc voltage and plasma gradient were obtained as a function of both arc current and electrode separation over a current range of 10 to 100 amperes. Results, verified by high-speed movies, show that the arc at close separations seems to have no anode flame and behaves as a cathodic discharge. The plasma gradient decreases with increasing current, but the gradient is not uniform throughout the region between the electrodes. The ratio of the arc voltage of the arc in argon to the voltage of the arc in helium is approximately the ratio of the first excitation potentials of these two gases. The presence of impurities on the electrodes will cause oscillations in the arc voltage.

Arc Welding Machine Characteristics as They Affect the Welding Arc; *George R. Wagner* (*Bureau of Ships, Washington, D. C.*).

The problem involved in accurately evaluating machine characteristics and attempting to define "arc stability" has been the subject of much research over many years by many separate organizations. The Navy specifications have tried to reflect the data obtained through Navy tests, research projects, and manufacturer's data. There still is much honest difference of opinion, and much further study of the problem is needed.

Recognizing the limitation in the completeness of data available to the Navy, the following machine characteristics are believed to be desirable in securing the most satisfactory arc welding performance:

1. Maximum short-circuit current, in load to short-circuit test, should not exceed approximately 500 per cent of the normal arc load setting.

2. Minimum short-circuit current, in a load to short-circuit test, should be above approximately 250 per cent of the normal arc load setting.

3. The rate of current rise seems to have an appreciable effect on arc stability. An arbitrary time constant factor of 0.015 to 0.020 second has been found generally the most satisfactory in conjunction with the other characteristics mentioned. This factor is roughly the L/R ratio and is directly determined as the time for the welding current to rise from zero, under open-circuit condition, to a value of approximately 63 per cent of the final value of welding current at normal arc voltage.

4. Recovery voltage overshoot, following a short circuit, is desired in the neighborhood of approximately 150 per cent of the normal arc voltage for the welding setting employed.

5. In addition to the instantaneous voltage overshoot, it is proposed that the minimum voltage dip at the electrode during the recovery period following short circuit be not less than 80 per cent of the normal arc voltage for the setting used.

6. The significance of the time for voltage and current to recover to normal following the instant of opening a short circuit has not been fully evaluated. It is proposed that a value of approximately 0.3 second be used.

7. Tests did not indicate that an open-circuit voltage above 80 volts was necessary and this maximum value is proposed.

8. It is proposed that a standard volt-ampere setting curve be adopted for arc welding machines. A suggested basis for measurements at the machine terminals is a straight line from 20 volts at 50 amperes to 45 volts at 500 amperes. Where manufacturers desire to provide for operation at various slopes for the volt-ampere curves it is proposed that major slopes be identified by symbols such as *A* setting, *B* setting, and so forth, yet retain the standard dial volt-ampere markings for each slope setting.

9. Although definite test evidence is not available, the Bureau of Ships has long felt that a design of machine, or an automatic device associated with a machine, to hold constant arc power for any setting, would help to improve manual welding.

It is intended that the Navy specifications for welders be modified to be in line with the foregoing characteristics. The various manufacturers' thoughts on these matters are invited.

Welding Characteristics of Mechanical Rectifier-Type Arc Welder; *K. L. Hansen* (*Milwaukee, Wis.*).

The motor-generator set has so far been the predominating type of equipment for conversion from alternating current to direct current for arc-welding purposes. From time to time arc-welding machines have appeared on the market in which the magnetic circuits of the motor and generator have been combined into one unitary structure.

Various modifications of the dynamotor type of welder have been on the market for periods of greater or less duration. The common feature of these machines is a double winding on the armature, one winding connected with slip rings to which a-c power is applied and the other connected to a commutator from which d-c welding current is drawn. They have differed mainly in the methods employed to obtain the drooping volt-ampere characteristic and current adjustment. The arc characteristics do not differ markedly from those of the conventional generator and, because of some drawbacks, they have not found extensive application.

Nevertheless, the idea of developing a d-c welder in a unitary magnetic structure will persist because of obvious advantages if it can be made to function satisfactorily. The writer became intrigued with the problem a number of years ago and soon arrived at the conclusion that its solution depended on the development of a successful synchronous mechanical rectifier.

With satisfactory conversion to direct current from alternating currents in a stationary winding accomplished, the remaining problems of designing a welder are relatively simple. Furthermore, a successful synchronous rectifier (rotating) has many fields of application and the development became, in general, concentrated on the problem of rectification, with welding more or less a side issue.

The rectifier welder consists of an ordinary induction-motor stator and rotor. In the stator slots is placed a 3-phase winding connected to the line which functions as transformer primary and also develops the torque necessary to drive the rectifier. In the same slots is placed a 2-phase winding which constitutes the secondary of the transformer. The two phases are connected respectively to brushes bearing on two segmented rings. These rings are internally connected in series and in turn are connected in series with two slip rings from which direct current is taken.

In addition to the squirrel cage, the rotor has a d-c winding connected to brushes bearing on the slip rings. While the rotor is slipping during starting, the current in this winding is alternating current of decreasing frequency and is converted to direct current when the motor pulls into synchronism. The pull-in torque is excellent, and the starting equipment required is the same as for an induction motor.

The voltage on each phase is approximately 50 volts and when rectified and connected in series produces an average of direct voltage of 90 volts. Superimposed on this is a 240-cycle ripple of appreciable amplitude. This ripple apparently has considerable influence on the arc characteristic and can, under certain conditions, be made to produce a high degree of stability. This makes it possible to perform welding operations which cannot be approached under same conditions with the conventional welding generator.

Hydraulic Control of Transformer-Type Arc Welders; *A. C. Mulder, G. K. Willecke (Miller Electric Manufacturing Company, Inc.).*

One of the limitations of the moving-coil type of welding transformer has always been its relatively slow current adjustment. This has presented no serious problem in normal metallic arc welding. The need for quick current adjustment for crater elimination in the "Heliarc" welding process, however, has recently focussed attention on this shortcoming.

The usual solution has been to use direct motor gear drive on the moving coil, to switch reactors into the welding circuit, or both.

The use of pressure rams, operating with compressed air or with oil, has been considered frequently, but generally presented too formidable a problem from the economic standpoint. After careful analysis and investigation it was felt that in spite of the foregoing objections, hydraulic operation using standard oil cylinders seemed to show considerable promise.

A heavy duty "Heliarc" welding transformer has been developed which uses this method of control. A closed circuit hydraulic system, using standard hydraulic components and electric remote control, results in a current control method that shows definite promise of approaching the ideal.

High-Frequency Induction Welding; *J. R. Bondley (General Electric Company).*

High-frequency induction heating of metals is an old and well-established process. It is widely used in industry for such applications as heat treating, soldering and brazing, and accelerating the drying of paint.

It is not generally appreciated that induction heating can be used to join metals directly, and without the use of additional fluxes or solders. To effect a weld, it is necessary to produce a high concentration of current for a controlled interval of time in the faying surfaces. The efficient production of concentrated radio-frequency fields requires that attention be paid to the design of the high-current conductors and the impedance-matching transformer.

The duration of the current must be controlled as in any form of resistance welding. This time control can be added at any one of several points in the oscillator system. The particular scheme employed is not of importance provided the duration can be accurately repeated.

Advantages of induction welding are numerous. It is inherently a high production system, a high efficiency system, and a low maintenance process. Deformation or excessive heating of the parts is avoided, and parts can be welded in controlled atmospheres as well as in air. The main disadvantages are due to the high investment for equipment and the rather narrow scope of application. Successful welding is usually limited to small parts having a circular geometry and constructed from iron or ferrous alloys.

An Ampere-Squared-Second Indicator for Resistance Welding; *N. P. Millar, A. A. Kavaliauskas (General Electric Company, West Lynn, Mass.).*

The quality and consistency of resistance welds depend on the control of a number of variables of which two of the most important are current and time. Up to now, these two quantities have been measured by separate measurement means. This has not been too satisfactory, since, for example, the measurement of currents that flow in a weld for only a few cycles cannot be accurately measured with conventional ammeters or even with pointer-stop ammeters.

The device described in this paper combines the measurement of amperes and time into one electrical quantity that is an integration of the ampere-squared-seconds of an applied welding current. The maximum deflection of this indicator is then a direct measure of the heat energy supplied to the weld. A bimetallic spring, heated by the impulse current passing through it, constitutes the basic operating element of the indicator. The nominal full-scale rating of this device is ten ampere-squared-seconds.

The instrument must be used in conjunction with a suitable current transformer that will supply ten ampere-squared-seconds at full scale. By the proper choice of transformer, the indicator can be adapted to measure heat energy of a weld over a 3,000- to 80,000-ampere range and a time range of 1 to 30 cycles on a 60-cycle-per-second basis. Overload protection is accomplished either by electronic or fusing means. The operating cycle of this instrument is sufficiently short for most welding operations.

It is hoped that this measuring device will find applications in the welding industry as a means of controlling the quality and providing consistency of resistance welds.

Design of Transformers for Resistance Welding Machines; *Dean L. Knight (National Electric Welding Machines Company).*

A discussion of transformer design for resistance welding machines would have been a rather controversial subject 15 years ago, as in those days the name-plate kilovolt-ampere rating of the transformer meant little other than that it was printed in English. This condition, of course, could not continue, and several years ago the AIEE in conjunction with Resistance Welder Manufacturers Association drew up specifications for the standardization of welding transformer ratings.

No attempt was made in this paper to discuss design procedure such as specific current densities, flux densities, and so on, but rather to discuss basis of transformer ratings and factors affecting the design as well as factors which should be of primary interest to power companies and users of welding equipment.

Factors which are considered are listed in the following, not necessarily in order of importance:

1. Basis of rating of transformers.
2. Transformer impedance.
3. Transformer efficiency.
4. Excitation.
5. Types of secondaries.
6. Insulating materials.
7. Construction.

Conclusions that can be drawn from a discussion of the foregoing are as follows:

1. Although present AIEE–RWMA Standards for transformer ratings can be improved, they certainly have gone a long way in eliminating the confusion that existed before the Standards were adopted.
2. Transformer impedance is much more important to transformer design than transformer efficiency.
3. Transformer efficiency is actually not too important a consideration. Much more important is welder efficiency—secondary amperes versus kilovolt-ampere input.
4. Due to intermittent type of load excitation, current is not nearly as important as it is in the case of power transformers.
5. Considerable improvement has been made in the performance of welding transformers in the past 20 years and accurate information on operating characteristics is now available to power companies and users.

Multitransformer Welding Presses; *Jack Ogden (General Motors Corporation, Detroit, Mich.).*

Multitransformer welding presses are being widely employed in high-production metal fabricating plants. It is common practice to tie these welding presses into a continuous-flow stamping press line, with mechanical handling equipment permitting automatic and semiautomatic transfer, loading, and unloading of the weld assemblies.

Although special purpose machines, they are frequently designed with interchangeable components which minimize obsolescence and model change cost. Presses may be pneumatically, hydraulically, or electromechanically driven. Welding power requirements are high and, in many cases, groups of transformers on a given machine may be "stagger-fired." The welding transformer must be readily interchangeable, compact, and designed for low-duty-cycle high-current loads. Secondary circuits may be of the series, direct, or "over and under" types.

In spite of limitations on spot spacing, metal thickness, and metal surface resistance, the series connection is most frequently used. This secondary arrangement greatly simplifies machine design with attendant maintenance advantages, in addition to reducing primary power requirements.

Multitransformer presses are extremely valuable production tools if they are carefully designed with utmost emphasis given to minimum maintenance requirements and maximum ease of maintenance when required. "Down-time" on a poorly designed or a poorly maintained machine can easily cancel out its production advantages due to the strategic location of these machines.

Ignitrons for Frequency-Changer Welders; *R. R. Rottier (General Electric Company, Schenectady, N. Y.).*

Frequency-changer resistance welding is so named because 3-phase 60-cycle power is converted to single-phase low-frequency power at the weld. The low frequency permits use of a long throat in the welding machine. Furthermore, the distribution of load on the three phases is favorable from the power-demand standpoint. Tube requirements, however, are more severe than in conventional single-phase welding. This paper reviews the circuit requirements and describes the ignitron tube design that has been developed for this service.

Outstanding characteristics of frequency-changer welding control are

1. Reduction of single-phase kilovolt-ampere demand.
2. Balanced power over three phases.
3. Reduced reactance drop in the secondary of the welding transformer.
4. Improved welding of aluminum, magnesium, and their alloys.

The frequency-changer circuit is basically a 3-phase rectifier circuit with intermittent duty. Therefore, the ignitrons are subjected to the requirements of rectifier operation; namely, fast commutation, initial high-inverse voltage per cycle, and high surge currents in the event of tube arcback. In addition, the tubes must be capable of carrying the high-peak forward current required in resistance welding.

Power-rectifier ignitrons have baffles between the anode and the cathode to aid deionization and to enable the tubes to withstand the severe requirements of rectifier-circuit commutation. This baffling, however, reduces the cross-section area and limits the peak current that can be carried. Since welder-control ignitrons have no baffling, the deionization time of these tubes is relatively long, and arcbacks are too frequent under the particular service requirements of frequency-changer control. Therefore, a modified design was required.

Tests on this new frequency-changer ignitron tube (Radio Manufacturers Association type designation *5822*) show that it will carry nearly twice the peak and average currents of the equivalent size single-phase tube and that it will conduct without arc construction twice the peak current of the equivalent size rectifier tube.

The Effect of the Duration of Voltage Dip on Cyclic Light Flicker; *L. Brieger (Consolidated Edison Company of New York, Inc., New York, N. Y.).*

Published information on the effect of cyclic voltage dip on light flicker seems to be confined to uniform pulsation, where the duration of the dip is one-half of each pulsation period. The object of the investigations discussed in this paper was to observe the influence of the length of the dip. Most of the tests were made with 100-watt incandescent lamps, but a limited amount of data were also collected on a 15-watt white fluorescent lamp. Dips ranging from one-half to ten cycles duration were imposed, and the frequency of the pulsation was varied between 30 and one-tenth per second. Magnitude of the dip was varied to establish the threshhold of flicker perception for intent and casual observation and to determine the range considered objectionable by observers.

The general trend of the observations indicated that the frequency and the duration of the dips both affect incandescent lamp flicker. Dip duration seems to have less effect on fluorescent lamps.

In another series of tests, brief disturbances were produced by switching capacitors into the circuit. Disturbing flicker could be produced by transients lasting a small fraction of a cycle.

Probabilities of Interference Between Resistance Welders; *W. K. Boice (General Electric Company, Schenectady, N. Y.).*

This paper presents calculated data concerning the probability that the voltage during a resistance weld will be inadequate because of the voltage drops due to other welders. This information is useful for design of power systems for supplying groups of welders.

The reciprocal of the probability calculated is the number of welds which can be expected to have adequate voltage, for every weld with inadequate voltage. In order to use the data for power system design, it is necessary to first determine the allowable probability (allowable weld spoilage rate due to voltage drop). Also, the demand kilovolt-amperage and power factor of each welder must be estimated so that each welder's contribution to voltage drop may be determined. Furthermore, the maximum allowable rms voltage drop for a satisfactory weld must be known.

The probability of exceeding the allowable drop for any selected welder is determined by the number of other welders, the proportions of allowable drop which each of these other welders can cause, the duty cycles of these other welders, and the ratios of their weld times to the weld time of the selected welder. The calculations take into account the effect of partial overlaps of weld times.

As system impedance increases, the voltage drop contributed by each welder increases, and this increases the probability of inadequate voltage. It is possible to determine the maximum system impedance which will not cause the allowable probability to be exceeded. This maximum impedance will usually correspond to minimum system cost. This cost is often substantially less than the cost of a system designed to provide adequate voltage with all machines welding exactly simultaneously.

Welding Power System With Series Capacitors at Main Transformer Primaries; *C. W. Wright (General Motors Corporation, Detroit, Mich.).*

Delco Products' electrical distribution system in the main plant at Dayton, Ohio, is completely new and modern. Special emphasis was given to the welding distribution, and because the requirement for voltage variation on welding equipment must not exceed a total of five per cent, series capacitors for compensation of system impedance were selected.

Series capacitors of sufficient size were used to reduce the transformer impedance of 5.5 per cent to less than 0.5 per cent. One transformer bank was installed to reduce the total kilovolt-amperage required. Low-reactance bus was used for risers in the multistoried buildings, also for main feeders on the floors, with concentric cable as individual feeds to the welders.

With series capacitors, low impedance can be maintained in the welding system during normal operation. In the event of faults either on the low-voltage distribution lines or on the main feeder from the welder substation, the series capacitors are automatically removed from the circuit and the transformer impedance then limits the short-circuit currents to low values which can be handled adequately by less expensive low-voltage switchgear. Likewise, the effects of the lower short-circuit currents on low-voltage bus are not so severe.

Motion pictures taken of the substation capacitor bank and feeders illustrate the type of distribution system, and pictures taken of the welder in operation with meters showing the fluctuation of voltage and current with the capacitors both in and out of the circuit, illustrate the results obtained. It is believed that motion pictures rather than a series of charts will more clearly show the efficiency of the system.

Digests of Papers Presented at First AIEE Power Conference

These are brief authors' digests of most of the papers presented at the first AIEE Power Conference, sponsored by the AIEE Committees on Power Generation, Industrial Power Systems, and System Engineering, to be held in Pittsburgh, Pa., April 19–20, 1950. These papers are not scheduled for publication in AIEE Transactions or AIEE Proceedings, nor are they available from the Institute.

Elements of System Capacity Requirements; *C. W. Watchorn (Pennsylvania Water and Power Company).*

The probable future loads and the availability of the generating capacity determine the system capacity requirements. The effects of the probable future loads depend on the probable seasonal trend of the daily peak loads, the probable load level as affected by variations in business conditions, and the probable variations in the daily peak loads resulting from variations in weather conditions. The availability of the generating capacity involves the number, sizes, and pressures, and perhaps other characteristics of the individual boilers and turbines, their forced outage experience or expectancy, and their arrangement in the various stations, the scheduled maintenance policy, and so forth, and in the event hydro capacity is involved, on the available water supply and its possible use in the daily, weekly, or seasonal loads.

The composite effect of these several elements on the system capacity requirements can be evaluated properly only by means of statistical or probability methods. There are two simple basic probability principles which are applicable to the determination of capacity requirements. The risk or chance of failure to carry the load for any given set of conditions thus evaluated, combined with judgment as to what is a desirable level of service reliability, provides the basis for decision as to the amount of additional capacity required for probable future conditions.

There are wide differences in the capacity required to provide some desired level of service reliability resulting from differences in the number, sizes, pressures, and arrangements of the individual boilers and turbines and in the maintenance policies, all of which are factors that can be controlled. Wide differences also result from the uncontrollable factors relating to the probable load level, the seasonal trend of the daily peak loads, and the probable variations in load resulting from business and weather conditions. These different results raise a serious question as to the significance of a so-called system reserve as a measurement of either the absolute or relative adequacy of the capacity provided.

The differences in the required installed capacity as affected by the number, sizes, pressures, and arrangements of the boilers and turbines must be considered as a factor in the over-all most economical system design, while the differences resulting from maintenance policies provide the basis for the most economical co-ordination of the capacity planning with the operating policies.

Economic Evaluation of Unit-Type Generating Stations; *W. J. Lyman, R. M. Buchanan, C. E. Mullan* (*Duquesne Light Company*).

The strong trend in recent years toward the construction of unit-type generating stations has raised the question in some minds of whether the adverse effect on reserve capacity required for maintenance and forced outages might not outweigh the reduction in cost per kilowatt achieved through these installations. It is, of course, well known that the cost of generating stations is substantially lowered when common steam headers, and all other common piping and equipment that they involve, are omitted from the design, so that each turbine is matched with a boiler of the same capacity, and operates independent of the steam supply to the other turbines. It is not so widely accepted however, that there is an increase in the amount of reserve generating capacity required when common steam headers are omitted.

It is the purpose of this paper to measure and compare these two effects by analyzing several typical cases.

Trend of New Station Costs; *A. E. Knowlton* (*Electrical World, New York, N. Y.*).

Interest in the rising costs for constructing and operating the post-war power plants is justifiably great. Fragmentary data have indicated that the spread from the least expensive to the most expensive is greater than ever. Consequently, a roundup of the component investment costs should help to show what factors are accounting for the high, medium, and low values.

Similarly the thermal design of the station as well as the price of labor and fuel affect the production costs to varying degrees capable of association with the design objectives. Further than this there are space factors which are indicative of variations in design philosophy. The analysis in tabular and graphic form should afford authentic and timely bases of comparison for those engaged in planning and operating plants under prevailing economic conditions.

Fire Fighting Problems at Generating Stations; *Joseph J. Shoemaker* (*The Detroit Edison Company, Detroit, Mich.*).

The most serious hazards during construction of generating stations are due to fire in wood forms, temporary wood and tar-paper housings, canvas covers, and gasoline or oil heaters. Fires may be caused by fuel oil, bearing oil under pressure, transformer and switch oil. Coal fires occur in stock piles, coal in preparation, and powdered fuel. Gas may cause fires or explosions. Fires in and around energized electric equipment are a further hazard. Cutting, welding, and painting are maintenance fire hazards.

A fire in a bag filter used with pulverized coal caused a loss of $35,000. This equipment is now protected by automatic water spray, using simple control equipment. A fire, caused by lightning breaking a bushing during a storm, completely destroyed a station transformer. Inexpensive light steel baffles were very effective in protecting adjacent transformers.

A fire protection program includes combination of design features, training of plant personnel, and co-operation with the local fire departments.

Steam-Electric Station Efficiency Control; *B. G. A. Skrotzki* (*Power, New York, N. Y.*).

The largest item of cost in running a steam-electric station is the fuel bill. For this reason the operating superintendent and test engineer keep a close watch on station heat rate. Any unusual deviation causes consternation and immediate investigation. For continuous operating guides such factors as boiler exit flue-gas temperature, steam-flow: air-flow ratio, turbine stage pressures, and exhaust pressure compared with load carried usually prove adequate. None of these, however, give a true indication of how well the entire station is performing at any given moment. There have been proposals for various types of heat rate meters but evidently none have proved practical.

Final measure of performance still is the ratio of heat input to electric output over the period of week, month, or year. Many factors affect the heat rate, always resulting in a degree of uncertainty as to the figure's acceptability. A method of checking actual against expected performance that eliminates any uncertainty features an allocation of heat rate change between two periods to all factors influencing station performance. This aids the supervisors in understanding station behavior and gives them a basis for evaluating proposals for improving performance.

Methods of Storing, and Control of Materials and Supplies; *A. Gastler* (*Consolidated Edison Company of New York, Inc., New York, N. Y.*).

The efficient operation and maintenance of a power generating station or any large industrial system must necessarily rely on an accessible and adequate supply of materials and spare parts.

It should be realized that the initial approach to the problem rests with the department which uses the material. Information as to what to stock, initial purchase quantity, nature of expected use, minimum stock level, and other pertinent data must emanate from this department. The stores department must then arrange to procure the supplies through the proper purchasing channels; receive, inspect, and store material; protect material from corrosion; provide proper handling equipment; maintain adequate records, and insure the proper flow of material requisitions to account for the supplies used. Modern storeroom facilities and self-service storerooms are recent improvements.

The problem of material control should rest with a division of the purchasing and stores who should be responsible for setting proper order point controls, issuing requisitions for stock replenishment, screening non-stock requisitions for possible substitutions from existing stock, conducting survey operations to dispose of inactive or obsolete items, and for co-ordinating material activities between all groups involved.

System Neutral Grounding in Industrial Plants; *D. L. Beeman* (*General Electric Company, Schenectady, N. Y.*).

The neutral of some classes of power systems have nearly always been grounded. The neutrals of other classes of power systems are seldom ever grounded. This situation has been due to code interpretations, standard transformer connections, and so on.

The trend in the last ten years has been definitely toward grounding the neutrals of all classes of industrial power systems. This practice is rapidly becoming well established in the 2.4- to 15-kv class of systems. The trend in the 480- and 600-volt class of system is starting toward system neutral grounding. This practice has been shown to improve service reliability, decrease operating cost, and increase safety.

Minimizing Industrial Production Losses Due to Voltage Dips; *E. L. Tornquist, E. A. Armstrong* (*Public Service Company of Northern Illinois*).

Modern manufacturing methods tend toward continuous processes where a momentary power interruption, such as caused by a lightning disturbance, often of less than one second in duration, can stop production on the entire line for hours.

It was found that many power users were not aware of the large percentage of these disturbances that a machine or motor will carry through and restart without production loss.

The number of momentary dips are generally much greater than the prolonged outages. The total time that the line is de-energized due to them is probably five to ten seconds out of 31,000,000 seconds in a year. In one case, the loss of production was known to be as high as four to five hours for a one-second outage, or 40 to 50 hours per year due to these causes. These losses were almost all eliminated by proper analysis of the problem and application of available equipment.

The Efficient Use of Operating Personnel; *J. A. Brooks, F. Van Olinda* (*Consolidated Edison Company of New York, Inc., New York, N. Y.*).

The efficient use of operating personnel is to the best interest of both a company and its employees. High production per individual is the chief factor in a high standard of living. It is the long term interest of all the workers. Employees of electrical utilities make their work a life-time career. It is therefore to their interest that their company be managed efficiently. The efficient use of operating personnel is a major factor in efficient electrical utility management.

There are six elements which contribute to the efficient use of operating personnel. These are: a full day's work, station design, adequate supervision, training, flexibility, and good industrial relations.

INSTITUTE ACTIVITIES

Three-Day Meeting in Providence Scheduled for North Eastern District

A program of broad interest has been arranged for the 3-day meeting of the AIEE North Eastern District to be held in Providence, R. I., April 26–28, 1950. Meeting headquarters will be in the Sheraton-Biltmore Hotel. A variety of subject matter appropriate for the locality of the meeting will be presented in seven technical sessions. A special program for the women, inspection trips to nearby industries, an informal banquet and dinner in the evenings assure a busy time. In addition, the Board of Directors of the Institute will meet at the Sheraton-Biltmore Hotel on Thursday, April 27.

On Friday morning, April 28, a Student Branch Conference will be held consisting of two technical sessions, one for undergraduate students and one for graduate students. Following this conference, there will be a luncheon at noon on Friday for the Student Chairmen and Student Branch Counselors.

ENTERTAINMENT

On Tuesday evening the District Executive Committee will meet for dinner. Wednesday evening, April 26, there will be a banquet at the Sheraton-Biltmore Hotel, to which the ladies are cordially invited; dress will be informal. At that time the principal speaker will be Truman H. Safford of the Charles T. Main Company, who will discuss "Water Power in New York and New England." There will also be a dinner meeting, Thursday, April 27, at the Johnson's Hummocks Sea Grill. This dinner will also be open to the ladies and dress should be informal. The principal speaker at this dinner will be Professor Charles H. Smiley of Brown University, who will give an illustrated talk on his recent trip through Siam.

LADIES' PROGRAM

A varied and interesting program has been prepared for the ladies visiting the meeting. The schedule of these events is as follows:

Wednesday, April 26

8:00 a.m. Registration

1:00 p.m. A "Get Acquainted" luncheon and bridge at the Warwick Country Club, overlooking Narragansett Bay.

6:30 p.m. Ladies invited to attend the banquet at the Sheraton-Biltmore Hotel with the men. Dress informal.

Thursday, April 27

9:00 a.m. The visiting ladies will board busses for a scenic tour of historic Newport, visiting the Breakers, beautiful mansion of the late Cornelius Vanderbilt, and other points of interest, a ride around the "Ten-Mile Drive," and luncheon at Christy's on the Wharf at Newport. This will be an all-day trip.

6:00 p.m. Ladies invited to attend the banquet at Johnson's Hummocks Grill with the men. Dress informal.

Friday, April 28th

10:00 a.m. A tour of the Trifari, Krussman, and Fishel. Inc. plant, makers of the lovely Trifari costume jewelry, returning to the hotel by 12 noon. No formal entertainment has been planned for Friday afternoon, but individual arrangements will be made for those remaining in the city for sightseeing, shopping, and so forth, or ladies may join men on inspection trips.

INSPECTION TRIPS

The following inspection trips have been arranged for those attending the North Eastern District Meeting. A nominal fee for transportation will be charged based on length of trip. All those participating in these trips are requested to register and use transportation facilities as arranged by the committee in charge.

Owens-Corning Fiberglas Corporation. This plant is one of the largest and newest of its type, producing glass yarn and glass cloth for industrial and general use. The tour will cover all phases of the manufacture and finishing of fiberglas, from its initial stage where glass is melted under pressure, forced through spinnerettes, and wound, to the final stages where the yarn is woven into plain or intricate designs and dyed in processes similar to those used in glazing pottery. The finishing process where glass cloth is heated to a semifluid state in order to mould in the finished appearance, yet retain individual fiber characteristics, should be very interesting. A tour through the plant's Research and Development Laboratory will also be included. Here one may glimpse things to come in the glass textile field. This trip will highlight electric equipment used in high-speed production processes, as well as provide many points of interest to all viewing the production of this type of textile material.

This trip is scheduled for Thursday afternoon, April 27.

Brown and Sharpe Manufacturing Company. Machine tools of latest design, featuring advanced applications of electric controls, will be shown in operation. In addition to the application of general individual motor drives, examples of unit motor drives for various functional operations will be shown. Use of electric controls for the operation of machines, including the more recently developed "automatic cycle, sizing and spark timing arrangements for grinding machines," will be exhibited in operation. Electronic gauging equipment will also be shown in use. Guests will also be shown the manufacture of the famous Johansson Gage Blocks.

This trip is scheduled for Friday afternoon, April 28.

Manchester Street Plant—Narragansett Electric Company. Members and guests of the AIEE will have an opportunity to visit the Manchester Street Station of the Narragansett Electric Company. In the last few years the Narragansett Electric Company has

Michigan Section Men Elected AIEE Fellows

At a recent meeting of the AIEE Michigan Section, three Michigan Section members were honored in a ceremony and presented with certificates and appropriate congratulations upon having been elected to the grade of Fellow of the Institute. Here, left to right, E. C. Balch, Michigan Bell Telephone Company, presents certificates to Raymond Foulkrod, Michigan Bell Telephone Company; W. C. Smith, Michigan Bell Telephone Company; and L. W. Clark, The Detroit Edison Company. The meeting also included a paper, "Automatic Message Accounting," by R. E. Bradstrum, Michigan Bell Telephone Company installed three 50,000-kw turbogenerators, operating at 11,500 volts, 3,600 rpm, 1,200 pounds per square inch, and 950 degrees Fahrenheit. Steam may be obtained from either oil or powdered coal. Each generator is connected through the nearby Franklin Square Substation to 11.5/115-kv transformers and 115-kv cable to the New England Electric System. Station service for each machine is obtained from transformers connected directly to its generator leads with an alternate source from the 11.5-kv bus at Franklin Square.

This trip is scheduled for Friday afternoon, April 28.

Vehicle Maintenance Shops—United Electric Railways Company. On this trip, participants will inspect the maintenance shop of the major transit company in Rhode Island in which is maintained the fleet of 275 trackless trolleys and 200 motor busses serving a population of 590,000 persons living in the metropolitan areas of Providence, Pawtucket, and Woonsocket. From its Stores Department stocking some 17,000 parts, ranging from cotter pins to complete motor and engine assemblies, to the temperature-controlled paint spray booth handling 1,200 paint jobs annually, this shop is one of the most modern vehicle maintenance shops in the United States. The United States Railways Company Shop has been designed to provide adequate facilities for the operation of a unique system of protective maintenance developed on this property and has been copied by many outstanding transit companies throughout the world.

This trip is scheduled for Friday afternoon, April 28.

United States Rubber Company, Bristol, R. I. The manufacture of copper wire and cable from the rod form to the completed product will be seen at this plant. Processes include drawing to size, annealing, tinning, formation of a conductor, insulating, conductor, and cable covering.

Types of wire and cable produced are bare wire, weatherproof, rubber-insulated braided, rubber-insulated lead-covered, rubber-insulated neoprene-jacketed, and thermoplastic-insulated conductors.

This trip is scheduled for Friday afternoon, April 28.

Tentative Technical Program

North Eastern District Meeting, Providence, R. I., April 26–28

Wednesday, April 26

9:30 a.m. Insulated Conductors

50-107. Power Factor Measurements on Polyphase and Multiconductor Cable Using Single-Phase Bridges. *E. W. Greenfield*, Anaconda Wire and Cable Company

50-121. Failure of Rubber Insulation Caused by Soil Micro-Organisms. *J. T. Blake, D. W. Kitchin, O. S. Pratt*, Simplex Wire and Cable Company

50-108–ACO.* Electric Cables for the Mining Industry. *R. B. McKinley, B. J. Mulvey*, General Electric Company

9:30 a.m. Instruments and Measurements

50-109. A New High-Accuracy Counter-Type Tachometer. *T. M. Berry, C. L. Beattie*, General Electric Company

50-110. A Direct Reading High-Voltage Capacitance Bridge. *A. H. Foley*, General Electric Company

DP. The Use of Electric Strain Gauges in Dimensional Measurement.** *E. L. Wallet*, Brown and Sharpe Manufacturing Company

50-111. Power Measurement by the Hook-on Method. *A. J. Corson, A. L. Nylander*, General Electric Company. Presentation by title only

50-116. A New Device for Calibrating Watt-hour Meters. *H. F. Robison, W. H. Wickham*, Commonwealth Edison Company. Presentation by title only

50-118. Resistance Wire Strain Gauges as Elements of the Wheatstone Bridge. *Vincent Petrucelly, Jr.*, American Machine and Foundry Company. Presentation by title only

2:00 p.m. Rotating Machinery

50-37. Analysis of Synchronous Machine Short Circuits. *R. D. Camburn*, Commonwealth Services, Inc.; *E. T. B. Gross*, Illinois Institute of Technology. Presentation by title only

50-119. Variable Speed Drive, Constant-Frequency Alternator. *G. G. Gould, E. Krupotich*, Naval Ordnance Laboratory

50-120–ACO.* Calculation of Capacitor-Excited Induction Generator Performance. *J. B. Friauf*, Bureau of Ships

50-117. Equivalent Circuits of the Shaded-Pole Motor With Space Harmonics. *Gabriel Kron*, General Electric Company

2:00 p.m. Mining and Metal Industry and Management

Wire Drawing Applications

DP. Electric Equipment for Wire Drawing Machines.** *W. E. Zelley*, John A. Roebling's Sons Company

DP. Installation of Wire Drawing Equipment.** *N. C. Dunbar*, John A. Roebling's Sons Company

The Engineer in Large-Scale Affairs

Address: L. L. Bosch, Jackson and Moreland, Engineers

Address: John Atkinson, City Manager, Cambridge, Mass.

Thursday, April 27

9:30 a.m. Computing Devices

DP. Digital Computers in Control Systems.** *C. R. Wieser*, Massachusetts Institute of Technology

DP. Electrostatic Memory for Information Systems.** *S. H. Dodd*, Massachusetts Institute of Technology

—PAMPHLET reproductions of author's manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.

—PRICES for papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in nine-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the Technical Program Committee ultimately will be published in Proceedings and Transactions; also, each is scheduled to be published in Electrical Engineering in digest or other form.

DP. Computer Experience in Extending Tube Life.** *E. S. Rich*, Massachusetts Institute of Technology

DP. Marginal Checking—Preventive Maintenance for Electronic Equipment.** *G. C. Sumner*, Massachusetts Institute of Technology

DP. New Developments in Pulsed Circuit Tests Equipment.** *R. Rathbone*, Massachusetts Institute of Technology

9:30 a.m. General Industry Applications, Textile Industry

DP. Use and Misuse of Electric Equipment in Textile Mills.** *S. Cowan*, Factory Insurance Association

DP. How Fires Start in Industry (Movie).** *C. F. Hedlund*, Factory Mutual Insurance Company

DP. Electronics in the Textile Industry.** *L. T. Jester*, General Electric Company

DP. Application of Single Motor Drives to Textile Finishing.** *Textile Industry Subcommittee*

2:00 p.m. Basic Sciences

50-115. The Calculation of the Capacitance of Coaxial Cylinders of Rectangular Cross Section. *G. M. Anderson*, Carnegie Institute of Technology

DP. Density Distribution of Transient Currents in Conductors.** *L. M. Vallese*, Duquesne University

DP. The LaPlace Transform.** *A. Boyajian*, General Electric Company

DP. The Use of the Heaviside Null-Unit Function in Operational Systems Based on the LaPlace Transformation.** *J. J. Smith, P. L. Alger*, General Electric Company

2:00 p.m. Special Industry Applications and Heating

50-112. Determination of Effective Oil Temperature in a Transformer. *M. F. Beavers*, General Electric Company

DP. Conductive Rubber Radiant Heating Panels.** *R. C. Cassidy*, United States Rubber Company

50-113. Transverse Flux Induction Heating. *R. M. Baker*, Westinghouse Electric Corporation

50-114. Classification of the Reference Frames of a Synchronous Machine. *Gabriel Kron*, General Electric Company

Friday, April 28

9:30 a.m. Undergraduate Student Branch Papers

9:30 a.m. Graduate Student Branch Papers

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* **ACO:** Advance copies only available; not intended for publication in *Transactions*.

** **DP:** District paper; no advance copies are available; not intended for publication in *Transactions*.

ADVANCE REGISTRATION

Please register in advance by promptly filling in and mailing the advance registration card enclosed with the mailed announcement. Registration should be completed at the Registration Desk on arrival at the meeting. Identification badges will be prepared for those who register in advance and these will be available at the Registration Desk.

An initial registration fee of $2 will be charged all members and $3 for all nonmembers. No fee will be required of enrolled students and the immediate families of members.

HOTEL ACCOMMODATIONS

It is most essential that hotel reservations be made directly with the Sheraton-Biltmore Hotel. The room rate schedule at this hotel is given in the following table:

	One Person	Two Persons
Rooms with double bed		
With tub bath	from $4.00	$6.50
With tub and shower	from 5.75	8.25
Rooms with twin beds		
With tub bath	from 5.75	8.75
With tub and shower	from 6.25	8.75
Salon Suites, Parlor and Bedroom—$18.00 per day.		

MEETING COMMITTEE

Members of the North Eastern District Meeting Committee are as follows:

E. R. Coop, General Chairman; E. M. Adams, Finance; E. G. Sturdevant, Technical Program; R. H. Porterfield, Publicity; F. N. Tompkins, Student Program; H. C. Rankin, Hotel and Registration; H. A. Baines, Entertainment; H. R. Blomquist, Trips and Transportation; Mrs. H. C. Rankin, Ladies Program

Future AIEE Meetings

AIEE Conference on Electric Welding
Detroit, Mich.
April 5–7, 1950

AIEE Electric Space Heating Conference
Rogue Valley Country Club, Medford, Oreg.
April 12, 1950

AIEE Textile Conference (South)
Georgia Institute of Technology, Atlanta, Ga.
April 13–14, 1950

AIEE Power Conference (Power Generation and Power Supply for Industrial Plants)
Hotel William Penn, Pittsburgh, Pa.
April 19–20, 1950

AIEE Textile Conference (North)
Sheraton-Biltmore Hotel, Providence, R. I.
April 27, 1950

North Eastern District Meeting
Sheraton-Biltmore Hotel, Providence, R. I.
April 26–28, 1950
(Final date for submitting papers—closed)

AIEE Conference on Electrical Engineering Problems in the Rubber and Plastics Industry
Portage Hotel, Akron, Ohio
May 5, 1950

AIEE Conference on Improved Quality Electronic Components
Washington, D. C.
May 9–11, 1950

Great Lakes District Meeting
Hotel Hayes, Jackson, Mich.
May 11–12, 1950
(Final date for submitting papers—closed)

AIEE Conference on Telemetering
Philadelphia, Pa.
May 24–26, 1950

Summer and Pacific General Meeting
Huntington Hotel, Pasadena, Calif.
June 12–16, 1950
(Final date for submitting papers—closed)

Middle Eastern District Meeting
Lord Baltimore Hotel, Baltimore, Md.
October 3–5, 1950
(Final date for submitting papers—July 5)

Fall General Meeting
Skirvin Hotel, Oklahoma City, Okla.
October 23–27, 1950
(Final date for submitting papers—July 25)

1951 Winter General Meeting
New York, N. Y.
January 22–26, 1951
(Final date for submitting papers—October 24)

Program Plans Under Way for Great Lakes District Meeting

An interesting and comprehensive technical program is being formulated for the AIEE Great Lakes District Meeting which will be held in Jackson, Mich., May 11–12, 1950, with headquarters at the Hotel Hayes. The program will be divided into four general categories: "Transmission and Distribution," "Magnetic Amplifiers," "Generators and Motors," and "Power Plants."

The subject of transmission and distribution will include papers on "Power Supply for Rural Territory," "13.8-Kv System Development," "Network Application to Small Towns," "Banking of Transformers," and "Chemical Brush Control on Rural Power Systems," which will be woven into the general theme: "The Economics, Design, and Operating Problems Relating to Public Utilities Operating in Small Metropolitan Areas With Medium- or Low-Density Load Areas and Extensive Transmission." In addition, papers on the following subjects will be presented: "Galloping Conductors," "Transmission Line Analysis," "Cathodic Protection," and "Ground Fault Neutralizers" as pertaining to their use on both transmission and distribution systems. The subjects of meters and also the new high-interrupting-capacity low-voltage power fuse will be discussed. To complete the transmission and distribution subject, a paper will be presented on "Transmission Substation Design."

Magnetic amplifiers, magnetic amplifier application, and comparison of magnetic and tube amplifiers will be covered in one of the sessions. This subject is prominent at the present time and should prove very interesting and enlightening.

Under the general heading of "Generators and Motors," it is planned to have papers on "Generators and Telephone Interference," "Air Compressor Drives," "Induction Motor Unbalance," "Generator Selection," and "Commutation of Universal-Type Motors."

The subject of "Power Plants" will cover power plant design and higher voltage generator insulation.

A paper on "Noise Evaluation of Fluorescent Lamp Ballasts" will be presented also.

Special sessions will be held for students attending the meeting. Thursday afternoon will be devoted to the presentation of graduate student papers. Two complete

The Bryce E. Morrow plant near Kalamazoo, Mich., with a capacity of 180,000 kw, is scheduled for inspection during the AIEE Great Lakes District Meeting in Jackson, May 11–12

sessions, in which undergraduate student papers will be presented, have been arranged for Friday, May 12. Dr. L. G. Miller, Dean of Engineering at Michigan State College, will be the speaker at the student luncheon on Friday, May 12, at noon.

Arrangements for inspection trips and for other activities are progressing very nicely and these features should prove enjoyable.

Information on hotel reservations appears in the March issue (*p 265*). If such reservations have not been made as yet, it is requested that those desiring to attend the meeting refer to this issue immediately and forward their reservations to the hotel of their choice.

Improved Quality Electronic Components to Be Discussed at Joint Conference

A Conference on Improved Quality Electronic Components is to be held on May 9, 10, and 11, 1950, in the Department of the Interior Auditorium, Washington, D. C. This conference is sponsored by the AIEE, the Institute of Radio Engineers, and the Radio Manufacturers Association, with the active assistance of the National Bureau of Standards and the United States Department of Defense.

The conference is a consolidation of several technical meetings on this general subject which had been individually projected by some of the sponsoring organizations. It was felt that a single major conference was definitely preferable to several smaller ones. Plans for the conference are being carried out by a General Steering Committee whose membership is drawn from the various sponsoring organizations.

This conference will bring together representatives of the electronic equipments industry, the electronic components industry, the Military Services, and Government laboratories to discuss the general problem of operational demands, ambient requirements, size and weight reduction, mass producibility, and simplified maintenance with the same high degree of dependability and service life now possible in certain electric equipments of other types. New trends in the design and fabrication of electronic equipments, improvement in assembly methods and in the quality of components and simplified maintenance through unitized equipment packaging will be emphasized in consideration of the general problem.

Session 1 will outline the problem and the broad aspects of its solution. The keynote address will initiate the program from the over-all viewpoint of the electronics

Tentative Conference Program

Improved Quality Electronic Components

Tuesday, May 9

Registration 8:00 a.m.–9:30 a.m.

10:00 a.m. Welcome

F. J. Given, Chairman, Conference Committee

10:05 a.m. Session 1

Chairman: *A. V. Astin*, National Bureau of Standards

Keynote Address. *F. R. Lack*, Western Electric Company

Needs for greater operational dependability, simplified maintenance, and producibility in electronic equipments. Viewpoints and statements of requirements for improved components, fabrication techniques, test and maintenance procedures, and so forth, as interpreted by users and producers of electronic equipment for various fields of application.

Military Equipment. *L. V. Berkner*, Carnegie Institute of Washington

Commercial Electronic Equipment. *D. E. Noble*, Motorola, Inc.

Home Use Electronic Equipment. *F. R. Rollman*, A. B. DuMont Laboratories

Air-Borne Electronic Equipment. *C. R. Banks*, Aeronautical Radio, Inc.

Industrial Electronic Devices. *E. D. Cook*, General Electric Company

Laboratory Instruments. *P. K. McElroy*, General Radio Company

2:00 p.m. Session 2. Unitized Design and Electronic Fabrication Techniques

Chairman: *C Brunetti.* Stanford Research Institute

Keynote Address. *C. Brunetti*

A survey of electronic assembly and fabrication techniques. Factors involved in the unitization of electronic systems.

Printed Electronic Circuits Applications and Aspects. *W. S. Parsons*, Centralab Division, Globe Union, Inc.

Miniature Printed Circuit Electronic Assemblies. *A. Gross*, Stewart-Warner

Stamped Wiring—Sprayed Copper Wiring. *W. H. Kleiver*, Minneapolis-Honeywell Regulator Company

Report on an Electronic Equipment Design. *R. M. C. Greenidge*, Bell Telephone Laboratories, Inc.

Heat Transfer in Miniaturized Unit Assemblies. *W. Wheeler*, Sylvania Electric Products Company

Hermetically-Sealed Amplifier Design and Application. *W. G. Wing*, Sperry Gyroscope Company

Recent Developments in Potted Circuits. *W. G. Tuller*, Melpar, Inc.

A Program Towards 100 Per Cent Reliability in Telemetering Components. *W. J. Mayo-Wells*, Applied Physics Laboratory, The Johns Hopkins University

Discussion Period

Wednesday, May 10

9:00 a.m. Session 3. Components

Chairman: *F. J. Given*, Bell Telephone Laboratories, Inc.

Keynote Address. *E. I. Green*, Bell Telephone Laboratories, Inc.

Capacitors—Users' Viewpoint. *C. E. Applegate*, Leeds and Northrup Company

Paper and Plastic Capacitors—Producers' Viewpoint. *Louis Kahn*, Aerovox Corporation
Discussion

Mica and Ceramic Capacitors—Producers' Viewpoint. *Byron B. Minnium*, Erie Resistor Corporation
Discussion

Electrolytic Capacitors—Producers' Viewpoint. *Gordon Peck*, P. R. Mallory Company
Discussion

Radio-Frequency Inductors and Transformers—Users' Viewpoint. *D. B. Sinclair*, General Radio Company

Radio-Frequency Inductors and Transformers—Producers' Viewpoint. *J. R. Mazzola*, Automatic Manufacturing Company
Discussion

Iron Core Transformers—Users' Viewpoint. *L. Batchelder*, Submarine Signal Division

Iron Core Transformers—Producers' Viewpoint. *Reuben Lee*, Westinghouse Electric Corporation
Discussion

2:00 p.m. Session 4. Components (Continued)

Chairman: *S. H. Watson*, Radio Corporation of America

Resistors and Potentiometers—Users' Viewpoint. *P. S. Darnell*, Bell Telephone Laboratories, Inc.

Composition Resistors and Potentiometers—Producers' Viewpoint. *Jesse Marsten*, International Resistance Company
Discussion

Wire-Wound Resistors and Potentiometers—Producers' Viewpoint. Ward Leonard Company (speaker to be announced)
Discussion

Connectors. *E. C. Quackenbush*, American Phenolic Corporation
Discussion

Indicating Instruments for Dependable Electronic Equipments. *J. H. Miller*, Weston Electric Instrument Corporation
Discussion

Miscellaneous contributed short papers on components

Thursday, May 11

9:00 a.m. Session 5A. Components (Continued)

Chairman: *D. G. Fink*, McGraw-Hill Publishing Company

Tubes—Application—Users' Viewpoint. *T.H. Schubert*, Sperry Gyroscope Company

Tubes—Application—Producers' Viewpoint. *T. B. Perkins*, Radio Corporation of America (Victor Division)

Improved Tubes—Octal Series. *G. D. Hanchett*, Radio Corporation of America (Victor Division)

Improved Tubes—Miniature Series. *R. E. Moe*, Kenrad Division, General Electric Company

Improved Tubes—Miniature and Subminiature Series. *P. T. Weeks*, Raytheon Manufacturing Company

Improved Tubes—Subminiature Series. *A. L. Dolnick*, Sylvania Electric Products Company

Improved Vacuum Tubes for Severe Operating Conditions. *J. Wyman*, Eclipse Pioneer Division, Bendix Radio Corporation
Discussion

Intermission

11:30 a.m. Session 5B. Panel Discussion and Open Forum

Panel Discussion Period

Mederator: D. G. Fink

Panel Members

Questions and Discussion

Summary Remarks

industry. Subsequent discussions will consider the problem in more detail, each from the viewpoint of the producer or user of electronic equipment in a specialized field.

Session 2 will cover the factors involved in unitized equipment design, new fabrication methods, and packaging for electronic assemblies. Representatives from industry will present engineering reports on novel features and assembly techniques.

Sessions 3, 4, and 5*A* will consider the performance and adaptability of the more common electronic components. Characteristics of components imposing limitations upon their adaptation to new design or ambient requirements will be presented from the point of view of the user, that is, the equipment designer. Most of the discussions on these sessions, however, are to be presented by producers of electronic components who will point up timely and pertinent advances in the technology of component design, manufacture, and application.

Session 5*B* will take the form of a discussion panel with moderator to focus attention on the points of principal interest which have arisen in the course of the conference. This will be followed by a general open discussion.

It is to be emphasized that the Program Committee has attempted merely to establish a general theme for the conference and to provide a general order for the presentation of subject matter. Each speaker is advised of his complete freedom in selecting the specific phase of his assigned subject which he considers the most fruitful utilization of his allotted time. His talk may be a general survey or a detailed treatment of specific aspects.

Technical Program Released for Atlanta Textile Conference

On April 13–14, the AIEE Conference on Electrical Application for the Textile Industry (South) will be held at the Georgia Institute of Technology, Atlanta, Ga. This conference is sponsored by the AIEE Subcommittee on Textile Industry (H. C. Uhl, Chairman) of the General Industry Applications Committee and the Georgia Institute of Technology. Following are the sessions:

Thursday, April 13

9:00 a.m. Registration

9:30 a.m. "Welcome to Georgia Tech"

The Use and Misuse of Electric Equipment in Textile Mills. *Swaffield Cowan*, Factory Insurance Association

Packaged Drives in the Textile Industry. *W. H. Behnke*, Reliance Electrical and Engineering Company

Connecting Power Wiring. Symposium and comments from the field, led by *Dan McConnell*, Cone Mills Corporation

12:30 p.m.

Noon luncheon and talk by Dr. H. A. Dickert, Director of the A. French Textile School, Georgia Institute of Technology

1:00 p.m.

Standardization of Range Drives for Textile Finishing. *R. R. Lang*, General Electric Company

A Completely Air-Conditioned Mill. *H. S. Colbath*, Bibb Manufacturing Company

Forty Years of Textile Lighting. *Frank E. Keener*, Decatur, Ga.

Friday, April 14

9:00 a.m.

Electronics in the Textile Industry. *A. T. Bacheler*, Westinghouse Electric Corporation

The Hysteresis Yarn Tension Device. *W. L. Butler*, *R. J. DeMartini*, General Electric Company

Slasher Drives Up-to-Date. *J. G. Stephenson*, Westinghouse Electric Corporation

The AIEE Textile Subcommittee also is planning a similar conference for New England which will be incorporated as a session during the North Eastern District Meeting in Providence, R. I. Papers to be presented at the session on April 27 are listed on the North Eastern District Meeting program (see page 366). In conjunction with this session, an inspection trip is planned to the Owens-Corning Fiberglas Corporation, Ashton, R. I., on the same day.

First AIEE Power Conference Scheduled for Pittsburgh in April

On April 19 and 20, 1950, the AIEE Pittsburgh (Pa.) Section will be host to the first AIEE Power Conference, sponsored by the AIEE Committees on Power Generation, Industrial Power Systems, and System Engineering. William Penn Hotel will be scene of the meeting. A total of 18 papers will be presented in four sessions, and subjects will be of practical interest to central-station and industrial plant designers and operators.

The two-day program is as follows:

April 19, 1950

Morning Session

Elements of System Capacity Requirements. *C. W. Watchorn*, Pennsylvania Water and Power Company

Economic Evaluation of Unit-Type Generating Stations. *W. J. Lyman*, *C. E. Mullan*, *R. M. Buchanan*, Duquesne Light Company

Survey of New Station Costs. *A. E. Knowlton*, *Electrical World* (magazine)

Fire-Fighting Problems in Generating Stations. *J. J. Shoemaker*, The Detroit Edison Company

Afternoon Session

Maintenance and Overhaul Scheduling. *W. C. Bryson*, Duquesne Light Company

Steam Station Efficiency Control. *B. G. A. Skrotzki*, *Power* (magazine)

Efficient Use of Operating Personnel. *J. A. Brooks*, *F. Van Olinda*, Consolidated Edison Company of New York, Inc.

Methods of Storing, Handling, and Controlling Material and Supplies. *A. Gastler*, Consolidated Edison Company of New York, Inc.

April 20, 1950

Morning Session

Modern Trends in Industrial Electric Power Distribution. *D. H. McIntosh*, Allis-Chalmers Manufacturing Company

System Neutral Grounding in Industrial Plants. *D. L. Beeman*, General Electric Company

Electrical System of a Pharmaceutical Plant. *J. M. Webb*, *R. H. Whaley*, Eli Lilly and Company

Selection of Voltage for Industrial Plants (Particularly Steel Mills). *H. B. Thacker*, Westinghouse Electric Corporation

Low-Voltage Switchgear for Large Commercial Buildings. *E. Burgin*, *A. Conangla*, I-T-E Circuit Breaker Company

Afternoon Session

Using 600- and 460-Volt Power Systems With Grounded Neutrals. *J. E. Arberry*, Pittsburgh Plate Glass Company

Minimizing Industrial Production Losses From Voltage Dips. *E. L. Tornquist*, *E. A. Armstrong*, Public Service Company of Northern Illinois

Supplying Power to Industry. *F. F. Dickman*, West Penn PowerCompany

Application of Capacitors to Industrial Systems. *J. E. Barkle*, *R. N. Bell*, Westinghouse Electric Company

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Will Rogers Memorial and Museum

Members driving to Oklahoma City from the east or north, to attend the 1950 AIEE Fall General Meeting, October 23–27, are urged to stop in Claremore, Okla., on Highway 66, 30 miles east of Tulsa, to visit the Will Rogers Memorial and Museum. Here will be found literally thousands of articles used by Will, types of saddles and riding gear from all over the world, and interesting letters from important personages in the United States and many foreign countries. A tour of the museum will take about an hour

AIEE Board of Directors Meets During New York Winter Meeting

The regular meeting of the AIEE Board of Directors was held at Institute headquarters, New York, N. Y., on Thursday, February 2, 1950, and concluded at the Hotel Statler, New York, on Friday afternoon, February 3.

The following resolution was adopted in memory of Past President Frank B. Jewett:

RESOLVED: That the Board of Directors of the American Institute of Electrical Engineers hereby expresses, upon behalf of the membership, keenest regret at the death of Doctor Frank B. Jewett, President of the Institute, 1922–23, Edison Medalist, 1928, Honorary Member, 1945, and one of its outstanding leaders; and that deepest sympathy be extended to members of his family.

The minutes of the Board of Directors meeting held in Cincinnati, Ohio, October 20, 1949, were approved.

The President was requested to send a letter of greeting to Past-President Dugald C. Jackson, on the occasion of his approaching 85th birthday.

Executive Committee actions on membership applications recommended by the Board of Examiners were reported and confirmed, as follows: As of November 23, 1949—59 applicants elected to the grade of Member, one Member reinstated, 204 applicants elected to the grade of Associate, two Associates reinstated, and 2,738 Student members enrolled; as of December 21, 1949—15 applicants transferred and two elected to the grade of Fellow, 57 applicants transferred and 25 elected to the grade of Member, 260 applicants elected to the grade of Associate, and 1,006 Student members enrolled.

Report was made of approval by the Board of Directors, by letter ballot, of recommendations of the Board of Examiners made at its meetings on October 27 and November 17, 1949. Recommendations of the Board of Examiners adopted at meetings on December 15, 1949, and January 19, 1950, were reported and approved; and the following actions were taken as recommended by the Examiners: 11 applicants were transferred to the grade of Fellow, 58 applicants were transferred and 40 were elected to the grade of Member, 218 applicants were elected to the grade of Associate, and 456 Student members were enrolled.

FINANCES

The Finance Committee reported, and the Directors approved, monthly expenditures as follows: November 1949, $84,991.67; December 1949, $78,502.12; and January 1950, $60,005.45.

A comparative statement of income and expenses for the period October 1, 1949, to January 31, 1950, and the same period last year, was reported, the figures indicating income as of the end of January amounting to 20.6 per cent of the budget amount for the current year, as compared with 20 per cent last year, and expenditures, with due regard to an inventory item, amounting to 34.2 per cent of the budget figure, as compared with 34.7 per cent last year.

The Board of Directors adopted a resolution dropping from the membership rolls any person owing dues for the fiscal year which began May 1, 1948, with a provision for reinstatement without the formality of an application, if the dues in arrears are paid prior to May 1, 1950.

A resolution was adopted continuing for the year beginning May 1, 1950, the present policy of accepting payment of membership dues from members in countries affected by abnormal exchange rates on the basis of the par currency value of such countries—the exchange allowance to correspond to the difference between the New York exchange value and the normal par of the country in question, and not to exceed 40 per cent of the dues payable and not to apply to purchases of or subscriptions to Institute publications; a corresponding reduction on appropriation payments to be applicable to Institute Sections in any countries affected.

The Board of Directors approved the practice of the Finance Committee's making, upon request, an advance payment of $250 toward the expenses of a special technical conference of the Institute, on the basis that the conference will be self-supporting and will repay the advance. So far, the Institute treasury has been reimbursed for all such advances, it was reported.

Upon request of the Engineers' Council for Professional Development and approval of the Finance Committee, the Institute's contribution to ECPD was increased from $1,920 to $2,100.

A request of the Engineers Joint Council was presented for a contribution to cover the Institute's share of expenses of the EJC Committee on National Water Policy in developing a program which, in brief, it is believed can render a distinctive and valuable service in relation to the temporary Water Resources Policy Commission recently appointed by President Truman; and, upon approval by the Finance Committee, it was voted to appropriate an amount not to exceed $1,000 for this purpose, contingent upon similar action by a majority of the other societies participating in EJC.

Upon recommendation of the Headquarters and Finance Committees, the former committee was authorized to proceed with plans for air-conditioning Institute headquarters offices, to increase effectiveness of operations at Institute headquarters during the very busy summer months through such improvement in working conditions.

Upon request of the Publication Committee, the Directors authorized the addition of one person to the editorial staff, required because of the increased number of special technical publications.

The Board of Directors discussed the question of raising the annual dues of Student members from $3 to $5, the present dues having been in force since the beginning, in 1903, and the expense of carrying Student members having increased tremendously since that time, costing during the last calendar year approximately $35,000 beyond the income from Student dues. The proposal will be considered further at the April meeting of the Board of Directors.

In accordance with Section 25 of the Bylaws, a resolution was adopted setting the date and place of the 1950 Annual Meeting of the Institute, namely, Monday morning, June 12, in Pasadena, Calif.

The following future meetings were authorized, as recommended by the Committee on Planning and Co-ordination:

1951: District 5 Meeting, Madison, Wis.; Spring Pacific General Meeting, Portland, Oreg.; August Fall General Meeting, Cleveland, Ohio, October 22–26 (Change from previously authorized dates)

and the tentative scheduling of meetings as follows was approved:

1952: Winter General Meeting, New York, N. Y., January 21–25
District 1 Meeting, Binghamton, N. Y., April 30–May 2
Pacific General Meeting, Phoenix, Ariz., early Fall

CHANGES AND AMENDMENTS

The Board of Directors approved in principle and referred to the Committee on Constitution and Bylaws for the preparation of the necessary amendments to the Bylaws, recommendations of the Committee on Planning and Co-ordination, as follows:

1. Change in name of "Co-ordinating Committee" to "Division Committee."

2. Designation of the chairman of the Division Committee as "Division Advisor."

3. Appointment of a new standing committee of ten members to be called "Technical Advisory Committee" (which will replace the present Technical Activities Subcommittee of the Committee on Planning and Co-ordination).

4. Membership of the new Technical Advisory Committee to consist of the five Division Advisors (formerly called Co-ordinating Committee Chairman), namely,

(*a*). Communication Division Advisor
(*b*). General Application Division Advisor
(*c*). Industry Division Advisor
(*d*). Power Division Advisor
(*e*). Science and Electronics Division Advisor

and

Chairman of the Technical Program Committee
Chairman of the Standards Committee

Three members-at-large to be appointed by the President, one of whom to be designated chairman of the committee.

5. The scope of the new Technical Advisory Committee to be to stimulate, promote, and encourage technical activities and specifically to be concerned with:

(*a*). All scopes of technical committees

(*b*). Special events which may involve committees in more than one division, such as Special Technical Conferences Symposia, and general procedure.

(*c*). Joint subcommittees and other technical committee organization.

(*d*). Assistance to the Technical Program Committee, the Standards Committee, and Planning and Co-ordination Committee, when solicited.

(*e*). Consideration of problems brought up by any Technical Division.

6. The chairman of the Technical Advisory Committee to be a member of the Committee on Planning and Co-ordination.

7. The several Division Advisors no longer to be members of the Committee on Planning and Co-ordination or Committee on Award of Institute Prizes.

Upon the suggestion of the chairman of the Technical Program Committee and of the Committee on Award of Institute Prizes, the Committee on Planning and Co-ordination recommended that Section 76 of the Bylaws be amended to effect a change in composition of the Committee on Award of Institute Prizes so that it will consist of five members-at-large, one of whom shall be the chairman, and two members appointed from each Technical Division. The Board of Directors approved this recommendation and referred it to the Committee on Constitution and Bylaws for submission of a proposed amendment to Bylaw 76 of the Constitution.

Upon recommendation of the Committee on Servomechanisms and the Committee on Planning and Co-ordination, the Directors voted to change the name of the former committee to "Committee on Feedback Control Systems."

Upon petition, and recommendation of the Sections Committee, the Board of Directors authorized full Section status for the Saginaw Valley Subsection of the Michigan Section, the new Section to be known as the Northeastern Michigan Section, with territory consisting of the following counties in the State of Michigan: Alcona, Alpena, Arenac, Bay, Cheboygan, Clare, Crawford, Genesee, Gladwin, Gratiot, Huron, Iosco, Isabella, Lapeer, Midland, Montmorency, Ogemaw, Oscoda, Otsego, Presque Island, Roscommon, Sanilac, Saginaw, Shiawassee, and Tuscola.

The Directors approved, upon request of the Syracuse Section and approval of the other Sections and District officers concerned, and recommendation of the Sections Committee, the transfer to the territory of the Syracuse Section of Essex, Franklin, and Clinton Counties in New York, from the territory of the Schenectady Section; Stormont County, Ontario, Canada, from the territory of the Ottawa Section; and Glengarry County, Ontario, from the territory of the Montreal Section. The intent of the transfer was to add these counties to the territory of the Northern New York Subsection of the Syracuse Section, the name of the Subsection to be changed to St. Lawrence International Subsection.

The following amendments to the Bylaws, offered by the Committee on Constitution and Bylaws at the suggestion of the headquarters staff, changing mail classification of dues statements and clarifying the procedure for dues payments, were adopted at the meeting:

Section 10. The second sentence was amended by the substitution of the word "mailed" for the words "sent by registered mail."

Section 17. The second sentence was amended by placing a period after the word "arrears," deleting the remainder of that sentence, and inserting in its place the following complete sentence: "The annual dues bill and each of the quarterly notices sent to those remaining in arrears shall have Sections 16, 17, 18, and 12 of the Bylaws printed on the reverse side."

The third sentence amended to read: Any member remaining in arrears on the following May first. . . ."

Acting upon a request of the Vancouver Section to be transferred to District 9 and recommendation of the Sections Committee, the Vice-Presidents of Districts 9 and 10, and the chairman of the Committee on Constitution and Bylaws, the Board of Directors voted to authorize the transfer of the Province of British Columbia from District 10 to District 9, and a travel allowance for the Vice-President of District 10 to visit the Vancouver Section once each year for the purpose of promoting AIEE activities in western Canada and to maintain contact in matters of purely Canadian interest; this travel allowance to be computed from the closest Section or Branch in District 10, and the matter of such travel allowance to be reviewed at the end of two years to determine whether or not its continuance is desirable.

A comprehensive and final report of the Special Committee on Policy Covering Institute Activities was presented, its recommendations were approved, and its publication in the March issue of *Electrical Engineering* in the form of a message from President Fairman, with a detachable return postal card for an opinion poll of the membership, was authorized (*EE, Mar '50, pp 191–4*). The special committee was discharged, with an expression of the Directors' appreciation of its services.

T. G. LeClair reported, for the information of the Board of Directors, on conferences held thus far by the Exploratory Group of representatives of 16 societies invited by the Engineers' Joint Council to discuss the possibilities of achieving greater unity in the engineering profession, and of its Planning Committee. Mr. LeClair represents the AIEE on this group.

A revised edition of the AIEE Standards Manual ("A Guide in Standardization Activities") was approved as recommended by the Standards Committee.

AIEE REPRESENTATIVES

The Board of Directors, for many years, has appointed Institute representatives on the Electrical Committee of the National Fire Protection Association, but in view of the fact that the Electrical Committee has been reorganized as the Electrical Section of NFPA and has a National Electrical Code Committee, and as during the past year the sponsorship of the National Electrical Code has passed from the Electrical Standards Committee of the American Standards Association to the NFPA, the AIEE Standards Committee recommended that the AIEE representatives on NFPA be appointed by the Standards Committee in accordance with the procedure now in force of delegating to the Standards Committee the appointment of AIEE representatives on other standardizing bodies. The Directors approved this recommendation.

The Standards Committee reported the appointment of the following AIEE representatives:

W. A. Del Mar and A. A. Jones, representative and alternate respectively, on ASA Sectional Committee *B32*, Wire and Sheet Metal Gauges.

H. Halperin and E. A. Miller, representative and alternate respectively, on ASA Sectional Committee *C9*, Magnet Wire.

George Sutherland, representative on ASA Sectional Committee *C37*, in place of Oscar Bauhan, who has been substituted for George Sutherland as an AEIC representative.

Sterling Beckwith and C. F. Scott, representative and alternate respectively, on ASA Sectional Committee *C73*, Attachment Plugs and Receptacles.

F. L. Snyder, J. E. Clem, H. M. Jalonack, chairman, representative, and alternate respectively on ASA Sectional Committee *C57*, Transformers.

J. E. Clem, representative, D. D. MacCarthy and S. C. Killian, alternates, on Standards Co-ordinating Committee 8, Insulation Co-ordination, which committee also represents the AIEE on the AIEE-EEI-NEMA Committee on Insulation Co-ordination.

R. L. Frisbie, appointed by AIEE as sponsor, a liaison representative of Mexico on ASA Sectional Committee on ASA Sectional Committee *C42*, Definitions of Electrical Terms.

The Standards Committee reported approval of the following:

Proposed revision of the American Standards for Relays Associated With Power Switchgear, *C37.1*, approved and submitted to ASA Sectional Committee *C37* for consideration.

The American Standard Letter Symbols for Aeronautical Sciences, *Z10.7*, approved by AIEE as one of the cosponsors of the *Z10* project.

A report on "Recommended Procedure of Good Engineering Practice for the Minimization and Reduction of Interference for Radio-Frequency Heating Equipment" approved for publication.

In response to an inquiry from ASA, approved, as a cosponsor of the *Z32* project, that project's entering into international standardization of graphical symbols by the International Organization for Standardization, as proposed by the Association Française de Normalisation

ANNIVERSARY OF STUDENT CONFERENCES AND OTHER ACTIONS

A proposal for publication in *Electrical Engineering* of a suitable article on the first Student Branch convention, which was held 25 years ago, in March 1925, at the University of Pennsylvania, Philadelphia, was referred to Vice-President Seeley with power.

It was decided to hold the next meeting of the Board of Directors in Providence, R. I., on Thursday, April 27, during the North Eastern District Meeting.

Various matters concerning Engineers Joint Council were discussed, and the President was empowered to appoint an AIEE member on a co-ordinating and reviewing committee of the EJC Committee on National Water Policy. (President Fairman subsequently appointed E. L. Moreland.)

An invitation for the President of the Institute or his appointed representative to serve on the Board of Governors of the Building Officials Foundation was considered and referred to the President with power.

At the Friday afternoon session, Mr. LeClair and Alex Van Praag, NSPE member of the Exploratory Group to discuss increased unity in the engineering profession, reported further on conferences of the Planning Committee of this group.

Professor F. O. McMillan, AIEE representative, presented a progress report of the Inter-Society Conference on Engineering Student Branches.

President Fairman reported the appointment of AIEE members of a joint AIEE-IRE exploratory committee on co-operation, as authorized by the Board of Directors by letter ballot.

A report of the Resumed Conference of Representatives of the Engineering Societies of Western Europe and the United States of America held in London, September 19–23, 1949, was presented. The Board of Directors voted to continue the Institute's participation in the conference, and approved various recommendations made by the conference last September.

An invitation to propose a person for the award of the 1950 Kelvin Medal was referred to the chairmen of the Edison and Lamme Medal Committees.

A recommendation of the Board of Examiners for the appointment of a Local Honorary Secretary in Pakistan was referred to the President with power.

In acceptance of an invitation to appoint two delegates to the Annual Meeting of The American Academy of Political and Social Science, the Board of Directors appointed W. F. Henn, Chairman of the Philadelphia Section, and E. P. Yerkes, Director, AIEE, as such delegates.

Upon the suggestion of the Committee on Registration of Engineers, the Directors approved the inclusion in the catalogue of membership in the Year Book of a designating symbol at the name of each member who indicates on the Year Book information card that he is a registered professional engineer.

The Board of Directors went on record as desiring increased interest in and prestige of the Fall General Meeting, and directed that a statement to this effect be given to the chairmen of technical committees and Division Advisors and published in *Electrical Engineering*.

Chairman McMillan of the Committee on Student Branches proposed a change in procedure in the appointment of Student Branch Counselors, transferring appointment by the President of the Institute to the Vice-Presidents, each to appoint the Counselors in his District. The Directors approved the proposal in principle, and referred it to the Committee on Constitution and Bylaws for submission of a proposed amendment to the Bylaws to accomplish the change.

Other matters were discussed, with no action.

There were present the following:

President—J. F. Fairman, New York, N. Y.

Past President—Everett S. Lee, Schenectady, N. Y.

Vice-Presidents—J. L. Callahan, New York, N. Y.; W. C. DuVall, Boulder, Colo.; A. H. Frampton, St. Catharines, Ontario, Canada; R. A. Hopkins, Los Angeles, Calif.; Richard McKay, Spokane, Wash.; G. N. Pingree, Dallas, Tex.; E. W. Seeger, Milwaukee, Wis.; W. J. Seeley, Durham, N. C.; Victor Siegfried, Worcester, Mass.; C. G. Veinott, Lima, Ohio

Directors—W. J. Barrett, Newark, N. J.; E. W. Davis, Cambridge, Mass.; W. L. Everitt, Urbana, Ill.; R. T, Henry, Buffalo, N. Y.; N. B. Hinson, Los Angeles, Calif.; M. D. Hooven, Newark, N. J.; F. O. McMillan, Corvallis, Oreg.; Elgin B. Robertson, Dallas, Tex.; H. J. Scholz, Birmingham, Ala.; E. P. Yerkes, Philadelphia, Pa.

Treasurer—W. I. Slichter, New York, N. Y.

Secretary—H. H. Henline, New York, N. Y.

By invitation, during the Thursday and Friday afternoon sessions, T. G. LeClair, an AIEE representative on the Exploratory Group invited by the Engineers' Joint Council to discuss increased unity in the engineering profession.

Pasadena Selected as Site for Summer and Pacific Meeting

The AIEE Summer and Pacific General Meeting for 1950 will be held in Pasadena, Calif., at the Huntington Hotel from Monday, June 12, to Friday, June 16. Tentative arrangements have been completed and a condensed schedule of events is given in the following. Any one planning a western vacation this summer will find many points of interest in that Southern California city. By combining a vacation with attendance at the Summer and Pacific General Meeting, one can make a stay in Pasadena and Los Angeles a highly interesting one.

However, due to a highly popular convention which follows the meeting, it is suggested that members plan to depart from the Los Angeles area by Saturday morning, June 17.

TECHNICAL PROGRAM

There will be technical sessions on each meeting day, with subjects of interest to all included in the program. Among the sessions in prospect is one on microwave applications sponsored by the Committee on Carrier Current. Another session is being organized on system planning based on practices of utilities in the Pacific southwest power area. Registration will begin on Monday morning, June 12, to be followed by the annual meeting. The remainder of the technical meetings are scheduled tentatively as follows:

Monday, June 12 (afternoon)

District Branch Prize Papers (Districts 2, 4, 6, 8, 10)
Transmission and Distribution
Electric Welding
Petroleum Industry

Tuesday, June 13

Transmission and Distribution
Planning of New Laboratory Facilities
Computing Devices
Relays
Land Transportation
Mining Applications

Wednesday, June 14

Transformers
Mining Applications
Radio and Television
Electronics and Instruments and Measurements
Metal Industry
Telephone Switching

Thursday, June 15

Microwave Applications
Protective Devices
Electronics and Instruments and Measurements
System Engineering
Carrier Current

Friday, June 16

Power Generation
Substations
Electronics and Nucleonics
Magnetic Amplifiers
Rotating Machinery
Pulp and Paper Mill Application.

ENTERTAINMENT

At this time details are not available, but it is known that the Summer and Pacific General Meeting Committee is planning an extensive and varied program of entertainment not only for the ladies, but for the men as well. Also in the planning stage is an interesting series of inspection trips which will be co-ordinated with the subjects of the technical sessions.

Members of the Summer and Pacific General Meeting Committee are

Fred Garrison, General Chairman; M. V. Eardley Vice-Chairman; E. L. Bettanmier, Secretary; J. H Vivian, Treasurer; R. A. Hopkins, Vice-President; N. B. Hinson, Director

Subcommittee Chairmen are

H. A. Lott, Technical Program; E. W. Morris, Registration; Bradley Cozzens, Finance; E. S. Condon, Hotels; E. W. Rockwell, Transportation; H. S. Warren, Sports; G. F. Rucker, Inspection Trips; W. O. Kyte, Publicity; G. T. Harness, Students; C. W. Schweers, Entertainment and Program; H. F. Rempt, Arrangements; Mrs. Fred Garrison, Ladies

Goodyear Airship—Kopec photo

Air view of the Huntington Hotel at Pasadena, Calif., headquarters for the 1950 AIEE Summer and Pacific General Meeting, June 12–16

Electric Space Heating to Be Conference Subject

Electric Space Heating will be the subject of a Special Technical Conference to be sponsored by the AIEE Committee on Domestic and Commercial Applications for its members and interested friends who wish to discuss this timely and important topic. The meeting is set for April 12, 1950, at the Rogue Valley Country Club in Medford, Oreg., and will include a general session in the evening from 7:00 to 10:00 p.m. No prepared papers will be presented, but for those wishing to present technical data there will be a preliminary meeting at 2:00 p.m. to make arrangements so that everyone who is interested can be heard.

Reservations may be made at the Hotel Medford for comfortable rooms with baths. Medford can be reached by air, train, or automobile, and the California-Oregon Power Company has offered to take care of transportation from the airport and to the Rogue Country Club. Arrangements are also being made to take side trips in the Medford area on April 13.

Anyone planning to attend the Conference on Electric Space Heating should notify J. C. Beckett, Wesix Electric Heater Company, 390 First Street, San Francisco 5, Calif. Prospective visitors desiring hotel reservations should write directly to the Hotel Medford.

Electric Welding Conference Set for Detroit, April 5-7

Final plans have been completed for the second Conference on Electric Welding, sponsored by the AIEE in co-operation with the American Welding Society and the Industrial Electrical Engineers Society in Detroit. The conference, which will be held in Detroit, Mich., April 5–7, will include sessions on "Arc Research," "Arc Machines," "Special Welding Processes," "Instrumentation," "Resistance Welding Machines," and "Power Supply." Brief authors' digests of most of the papers presented at these sessions appear elsewhere in this issue (*pp 361–3*).

For a complete listing of papers and authors presently scheduled for presentation, see the tentative program in the March issue of *Electrical Engineering* (*EE, Mar '50, p 266*).

Student Branches to Convene at Georgia Institute of Technology

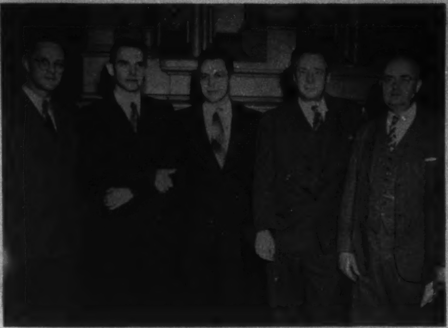
A convention of Southeastern AIEE Student Branches will be held at the Georgia Institute of Technology, Atlanta, Ga., April 12–15, 1950. The tentative schedule calls for a smoker on Wednesday evening, a banquet on Thursday, a dance Friday night, and a final business session on Saturday morning. Papers will be presented Thursday and Friday mornings. Sight-seeing tours are being scheduled to interesting sights around Atlanta.

Between two and three hundred student delegates are expected to attend the convention. Among the prominent visitors will be Dr. K. B. McEachron, Professor W. J. Seeley, and William E. Mitchell.

Chicago Section Holds Most Successful Meeting

The AIEE Chicago Section held one of the most successful meetings of its history on Thursday, February 9, 1950, in Mandel Hall, University of Chicago. More than 900 members and guests attended.

Dr. S. K. Allison, Director of the Institute for Nuclear Studies, University of Chicago, and Dr. John Marshall, University of Chicago, presented most interesting talks on basic nuclear research and, with slides, explained some of the principles involved. Merits of the first "atom smashing" machines were discussed and their performance was compared with performance expected from the 100-million-volt betatron and the 450-million-volt synchro-cyclotron which are now being installed.



At the AIEE Chicago Section's meeting on atomic research, left to right: Dr. V. L. Wesby, General Motors Corporation; Dr. G. M. L. Sommerman, Northwestern Technological Institute; Dr. John Marshall and Dr. S. K. Allison, University of Chicago; M. S. Oldacre, Utilities Research Commission

In conjunction with the talks, the groups visited the new laboratory where the betatron and synchro-cyclotron are being installed. Guides explained some features of the machines and plans for their use.

The crowd overtaxed both the meeting hall and laboratory space so that it was necessary to divide the group, having some for the lecture while others visited the laboratory and then interchanging the groups.

Dr. G. M. L. Sommerman and M. S. Oldacre were instrumental in arranging the program.

Lima Subsection Hears Federal Communications Commissioner

Robert F. Jones, Commissioner of the Federal Communications Commission, spoke to the AIEE Lima Subsection (Dayton Section) at their regular meeting on February 9, 1950. His subject was "The Dynamic Art of Television."

Mr. Jones has been a member of the Federal Communications Commission since July 1947. Prior to that he was Congressman from the 4th Ohio District. He practiced law and was Prosecuting Attorney in Lima before he became a Congressman in 1939.

There were 45 members, 33 Student members, and 43 guests present, making a total of 121. The Student members were from the Ohio Northern University Student Branch at Ada. B. O. Austin is Chairman of the Lima Subsection. Other officers are H. C. Doughty, Vice-Chairman; O. M. Swain, Secretary-Treasurer; E. S. Reed, Assistant Secretary; and W. R. Ankrom and F. C. Horn, Directors.

District 3 and New York Section Sponsor Meeting of Students

A meeting of the District 3 Student Branches jointly sponsored by District 3 and the New York Section was held February 21, 1950, in the Engineering Societies Building, New York, N. Y., with John L. Callahan of District 3 presiding.

President Fairman, the first speaker, told the audience of more than 100 students that the Institute needs new members continually—graduate engineers who will participate in all phases of Institute activities. He emphasized that it was only by growing up with the Institute that they would profit by the interchange of ideas and activities.

Mr. Fairman urged his listeners to take the examination on fundamentals for the state registration of engineers as soon after they were graduated as possible. Furthermore, they should take the second examination to demonstrate their professional competence so that they can obtain a license in order to practice engineering under the law. "License laws should be uniform throughout the country;" he said, "they are a fact, so be realistic about the registration and get your license."

W. Keister of the Bell Telephone Laboratories explained the use of relays in his talk, "Automatic Control With Relays." He first described the fundamental functioning of relays and then demonstrated how they are used to control various circuits by means of charts and apparatus. He showed how relays played an important part in the modern system of the dial telephone.

1951 Fall General Meeting Committee. According to a recent announcement, AIEE President Fairman has appointed the following members of the general committee to make plans for the AIEE Fall General Meeting which is to be held in Cleveland, Ohio, October 29–November 2, 1951:

D. E. Moat, General Chairman; W. R. Hough, Vice-Chairman; J. D. Leitch, Technical Program Chairman; F. E. Harrell, Nontechnical Co-ordinator; C. J. Beller, Finance Chairman; V. A. Diggs, Secretary-Treasurer; O. N. Jones; J. C. Strasbourger.

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

General Applications Group

Committee on Domestic and Commercial Applications. (*Carl F. Scott, Chairman; O. K. Coleman, Vice-Chairman; V. G. Vaughan, Sr., Secretary.*) The widespread interest in electric heating of homes and in heat pumps

Two views of the Ruud power plant of the Hol hydroelectric development at Hallingdale, Norway

was manifest at the packed conference session on February 3, 1950. Home owners' satisfaction with electric heating in several areas where it has been attractive is certain to lead to an increasing number of engineering problems concerned with adequate power supply, control of peak loads, and many others. A special technical conference on these topics will be held on the Pacific Coast at Medford, Oreg., on April 12, guided by subcommittee chairman, J. C. Beckett.

Readers will be interested in the photographs reproduced elsewhere on this page which were taken last summer by H. H. Watson (M '47). They are views of the Ruud power plant of the Hol hydroelectric developments in Hallingdale, Norway, 187 kilometers northwest of Oslo. When completed, this station, operating at 408 meters head, will deliver 250,000 horsepower at 200 kv to Oslo. Practically all of the energy produced is to be used for electric heating of homes.

The committee plans a special technical conference on domestic appliances in May or June in Cleveland, under the guidance of subcommittee chairman, T. H. Cline.

Industry Group

Committee on Industrial Power Systems. (*J. S. Gault, Chairman; H. G. Barnett, Vice-Chairman; S. A. Warner, Secretary.*) At a meeting of this committee, held during the recent Winter General Meeting, the committee acted upon a proposal to establish subcommittees on a rather permanent basis to act on industrial plant problems as they arise.

It was voted also that an Executive Subcommittee be established to advise on committee problems and to organize meeting activities. This subcommittee will be composed of the chairman, vice-chairman, and secretary of the main committee and the chairmen of the subcommittees. The following additional subcommittees were considered necessary at this time and chairmen were appointed by the chairman of the main committee: Industrial Plant Grounding—D. L. Beeman, Chairman; Transformer Ratio—H. G. Barnett, Chairman; Interior Wiring Design for Commercial Buildings—B. F. Thomas, Chairman; Industrial Plant Power Supply—A. E. Marshall, Chairman.

Power Group

Committee on Carrier Current. (*S. C. Bartlett, Chairman; C. W. Boadway, Vice-Chairman; E. W. Kenefake, Secretary.*) The majority of the work of this committee is proceeding along lines established some time ago as a continuing function of each of the several subcommittees.

The matter of microwave applications has only recently become a function of this committee, and the members are pleased to note the very large interest already appearing. This was evidenced at last year's Summer General Meeting in Swampscott and has encouraged plans for another session.

For some time the committee felt the need for a comprehensive bibliography on carrier current papers. The vice-chairman has assembled such a list for everything written prior to 1946 and this is now being brought up to date.

Subcommittee on Operating Experience With Carrier Current Relaying Channels has been especially active in circulating a memorandum of considerable detail to operating power companies, seeking information on performance over as many years as possible of these channels. Information is asked regarding test methods, inspection procedures, types of equipment, tube life, operating frequencies, power levels, outage time, and so forth. Considering the fact that for any recipient to fill out in the requested detail one of these questionnaires involves considerable effort, the committee has been very much encouraged by the excellent response to date.

Committee on System Engineering. (*Earle Wild, Chairman; R. Brandt, Vice-Chairman; O. W. Manz, Jr., Secretary.*) The Committee on System Engineering has undertaken several studies of specific subjects of general interest in its field. In August 1949, the Systems Controls Subcommittee released a report on the "Status of Automatic Load and Frequency Control Equipment" covering the practices of 53 hydro and 54 steam plants.

The Interconnection Contracts Subcommittee is in the process of revising and preparing in final form its examination of some 16 agreements between operating utilities.

The committee, through joint subcommittees, is engaged in the study of switching failures on tie line, probability in connection with system capacities, and economic comparison of alternate facilities.

Joint Subcommittee on Application of Probability Methods to Capacity Problems. (*G. Calabrese, Chairman; V. A. Thiemann, Secretary.*) The application of probability methods to engineering problems has increased tremendously in recent years and is still increasing every day. Broadly speaking, the work of this subcommittee is concerned with the application of probability methods to electric power problems, in particular to problems of reserve capacity of electric equipment, such as turbo units, boilers, and feeders.

Four papers sponsored by this subcommittee were presented at the AIEE Cincinnati General Meeting last fall. The subcommittee has now under way a project for the collection and analysis of basic outage data of a high-pressure generating unit and boilers. These data are essential to the determination of generating capacity reserve. The data will be collected by the Edison Electric Institute and analyzed by the Consolidated Edison Company.

Feeling that in the hydroelectric systems probability methods can be used to great advantage, the subcommittee is planning a symposium for the 1951 Winter General Meeting on the reserve practices of a hydro plant. The objective of this symposium is that of divulging these practices and of stimulating the application of probability methods to hydro systems.

The subcommittee also has under way the analysis of data already collected on "Methods of Load Scheduling and Practice of Spanning Reserve."

Other projects include: terminology, having as its objective the co-ordination of the terms now used in connection with reserve problems and recommendation of new ones as necessitated by the probability method; further development of short-cut method for determining reserve by the probability method; application of the probability method to the allocation of reserve savings derived from interconnections; reactive kilovolt-ampere reserve requirements; transformer and feeder reserve requirements—how consistent are the feeder and transformer reserve practices currently in use?; and extensive application of the probability method to the economic evaluation, from the standpoint of reserve, of alternative schemes of supply.

Science and Electronics Group

Joint Subcommittee on Standard Frequency Bands and Designations. The Joint Subcommittee on Standard Frequency Bands and Designations has been reactivated, under the chairmanship of G. B. Ransom. In addition to Mr. Ransom, who represents the Communication Co-ordinating Committee, other members are F. B. Silsbee, representing American Standards Association Sectional Committee *C68;* J. E. McCormack, representing ASA Electric Light and Power Group; T. P. Kinn, representing AIEE Electronics Committee; and D. B. Sinclair, representing AIEE Instruments and Measurements Committee.

Under the chairmanship of Thomas Spooner, who has recently resigned from the subcommittee, a "Proposed Frequency Band Designations" report was prepared and published in the August 1949 issue of *Electrical Engineering* (*p 672*). The present subcommittee will welcome comments on this report, as they will continue and expand this work.

Subcommittee on Electrical Tests on Dielectrics in the Field. The Subcommittee on Electrical Tests on Dielectrics in the Field of the Instruments and Measurements Committee has prepared a questionnaire on current practices in this type of testing. This questionnaire has been sent to approximately 200 representative power companies during the past month. The subcommittee plans to present a report to the Institute based on the results of the questionnaire, after the replies have been analyzed, subsequent to May 1, 1950, the closing date for data. This survey is so important that it would have been desirable to have data from practically every power company in the United States.

Since such a wide distribution is economically impossible it is hoped that this notice will come to the attention of any interested party. Any power company which did not receive a copy of this questionnaire but has data which it is believed would be of value in this survey may obtain copies by writing to R. S. Gardner, Assistant to the Secretary, AIEE Headquarters, 33 West 39th Street, New York 18, N. Y. Any contribution will be appreciated.

AIEE PERSONALITIES.....

1949 Lamme Medal Awarded to Laffoon

Carthrae Merrette Laffoon (A '24, M '39, F '45), Manager of A-C Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been awarded the 1949 AIEE Lamme Medal "For outstanding contributions to the design of electrical machines, particularly large turbine generators and high frequency generators." Mr. Laffoon was born in Coldwater, Kans., August 14, 1888, and was educated at the Warrensburgh (Mo.) State Teachers' College and the University of Missouri, where he received the degree of Electrical Engineer in 1914 and a Master of Arts degree in 1915. He has been associated with the Westinghouse Electric Corporation for 34 years and assumed his present position in 1938. From 1915 to 1916 he was an engineering inspector for Black and Veatch Consulting Engineers, Kansas City, Mo. Mr. Laffoon has been author of many papers presented before the Institute on all phases of a-c electric machine design and holds patents on improvement in high-frequency generators, ventilation, and double winding generators. He has been a member of the Board of Examiners since 1945 and was a Director of the Institute from 1942 to 1947. He has also served on the following committees: Electric Machinery (1934–37, Chairman 1938–40, 1940–45); Power Generation (1943–47); Lamme Medal (1942–46); Edison Medal (1943–45); Nominating; Power Transmission and Distribution (1943–44); and Technical Program (1938–40). Mr. Laffoon's engineering affiliations include the American Society of Mechanical Engineers, The Engineers' Club (New York City), Sigma Xi, and Tau Beta Pi.

C. M. Laffoon

T. G. LeClair Nominated for Institute Presidency

Titus George LeClair (A '24, M '29, F '40) Assistant Chief Electrical Engineer, Commonwealth Edison Company, Chicago, Ill., has been nominated for the presidency of the AIEE for the 1950–51 term. He was born in Superior, Wis., August 26, 1899, and received the degree of Bachelor of Science in electrical engineering from the University of Idaho in 1921. From 1922 to 1923, Mr. LeClair was with the General Electric Company in the student course and later in 1923 began his career in the Commonwealth Edison Company, holding various engineering positions with the company up to the time of his appointment as Assistant Chief Electrical Engineer in 1948. Mr. LeClair's outstanding engineering work has included the invention of devices used in the electrical industry, namely, relay schemes, switching schemes, automatic printing meters, and special conductors. He has presented papers before technical societies and has had many papers published in the technical press. Mr LeClair served as Vice-President representing District 5 (1946–48) and has been a Director of the Institute (1941–45, 1946–48). He has been Chairman of the Professional Group Co-ordinating Committee since 1947 and has also served on the following committees: Membership (1930–35); Protective Devices (1931–35, Chairman 1942–43), Legislation Affecting the Engineering Profession (1940–41); Land Transportation (1941–42); Edison Medal (1942–44); Standards (1942–43); Technical Program (1942–43); Award of Institute Prizes (1942–43, 1948–50); Registration of Engineers (1942–47); Student Branches (1945–46), Lamme Medal (1947–49); and Education (1949–50). Mr. LeClair was Chairman of the Chicago Section from 1929 to 1930 and has represented the Institute on the Engineering Societies Joint Committee on the Chicago Century of Progress Exposition in 1933 and the Advisory Board of the National Bureau of Engineering Registration (1946–

T. G. LeClair

J. G. Tarboux

C. S. Purnell

J. R. North

H. R. Fritz

J. A. McDonald

47). He is a Director and Past-President of the Illinois Engineering Council, a Past-President of the Western Society of Engineers, and a member of the Illinois Society of Engineers, the National Society of Professional Engineers, and Sigma Nu.

Vice-Presidential Nominees are Tarboux, Purnell, North, Fritz, McDonald

Joseph Galluchat Tarboux (A '21, M '32, F '43), Professor of Electrical Engineering at Cornell University, Ithaca, N. Y., has been nominated to serve the Institute as Vice-President representing the North Eastern District (number 1). He was born August 15, 1898, in Juiz de Fora, Minas Geraes, Brazil, and was graduated from Clemson Agricultural College in 1918 with a Bachelor of Science degree in electrical engineering and mechanical engineering. Dr. Tarboux received the degree of Electrical Engineer in 1923, Master of Electrical Engineering in 1926, and Doctor of Philosophy in 1937, all from Cornell University. Prior to receiving his present appointment as Professor of Electrical Engineering at Cornell University in 1946, Dr. Tarboux was an instructor at Clemson College (1918–19), instructor and Assistant Professor at Cornell University (1918–29), and Professor and Head of the Electrical Engineering Department at the University of Tennessee (1929–46). His industrial experience started during the summer of 1917 with the Public Service Corporation of New Jersey, and, subsequently, additional summer work with the Florida Power and Light Company, Alabama Power Company, Westinghouse Electric Corporation, and General Electric Company. Dr. Tarboux is the author of a textbook on electric power equipment, a second book dealing with electric power systems, and is a contributing author for the "Standard Handbook of Electrical Engineering." He has served the Institute as Chairman of the East Tennessee Section from 1940 to 1941 and as a Student Branch Counselor (1930–41, 1945–46), as well as the following committees: Membership (1941–43); Education (1943–49, Chairman 1946–48); Standards (1946–47); Award of Institute Prizes (1946–47); Technical Program (1946–48); and the Hoover Medal Board of Award (1947–53). Dr. Tarboux is a member of the American Society of Engineering Education, and of the following: Eta Kappa Nu, Phi Kappa Phi, Tau Beta Pi, and Sigma Xi.

Clayton Spence Purnell (A '29, M '35), Industry Supervisor, Industrial Sales Department, Westinghouse Electric Corporation, New York, N. Y., has been nominated to serve the Institute as Vice-President representing the New York City District (number 3). Mr. Purnell was born in Frostburg, Md., on June 17, 1902, and received a Bachelor of Science degree in mathematics and physics from Washington College, Chestertown, Md. He received his early engineering training attending night classes at Carnegie Institute of Technology, Pittsburgh, Pa., where he took electrical engineering courses. During the summers of 1918–1922, Mr. Purnell installed transmission line and power equipment for the Potomac Edison Company. From 1922 to 1923, he worked for the Westinghouse Electric and Manufacturing Company and during the latter part of 1923 was an engineer-apprentice for the New York, New Haven, and Hartford Railroad Company. Mr. Purnell returned to the Westinghouse Company in 1924 as an application engineer in railway equipment in their East Pittsburgh plant, and in 1927 became the New York transportation representative for the company. He has remained with the Westinghouse Company since 1927, attaining his present position of Industry Supervisor in 1946. Since 1948, Mr. Purnell has been Chairman of the Headquarters Committee and Vice-Chairman of the Sections Committee on which he has been a member since 1943. He was District Secretary (number 3) from 1944 to 1945 and his New York Section activities include Secretary (1941–42), Chairman (1943–44), and Chairman of the Transportation Division (1934–35).

John Rainsford North (A '21, M '29, F '41), Vice-President, Commonwealth Associates, Inc., Jackson, Mich., has been nominated to serve the Institute as Vice-President representing the Great Lakes District (number 5). Mr. North was born on February 20, 1900, in Cambridge, Mass., and was graduated from the California Institute of Technology in 1923 with a Bachelor of Science degree in electrical engineering after serving as Assistant Instructor in the Electrical Engineering Department. While studying for his degree, Mr. North worked as night substation operator for the Southern California Edison Company. Following a year as a graduate student with the Westinghouse Electric Company in East Pittsburgh, Pa., he became associated with the Commonwealth and Southern Corporation, reaching the position of Chief Electrical Engineer in 1945. In 1949, when the Commonwealth and Southern Corporation was reorganized as Commonwealth Services, Inc., with a wholly owned engineering subsidiary, Commonwealth Associates, Inc., Mr. North was appointed Vice-President of the latter organization. Mr. North was Chairman of the Michigan Section from 1934 to 1935 and had also served the Section as Secretary (1933–34). He was a Director of the Institute from 1945 to 1949 and has served on the following committees: Protective Devices (1934–47, Chairman 1940–42); Electric Machinery (1936–42); Technical Program (1940–44, 1947–49); Economic Status of the Engineer (1940–41); Standards (1941–50, Chairman 1942–44); Planning and Co-ordination (1942–44, Chairman 1947–49, 1950); Standards Council, American Standards Association (1943–45); Electrical Standards Committee, American Standards Association (1942–45); Air Transportation (1944–46); Edison Medal (1945–47, 1949–51); Switchgear (1947–50); Publications (1946–47); Professional Group Co-ordinating (1948–49); and American Standards Association (1948–49). Mr. North has actively participated in engineering affairs as a member of the Michigan Engineering Society, the Society of Automotive Engineers, and Tau Beta Pi.

Harry Reinhart Fritz (A '23, M '29, F '39), Chief Engineer, Southwestern Bell Telephone Company, St. Louis, Mo., has been nominated to serve the Institute as Vice-President representing the Southwest District (number 7). Mr. Fritz was born in St. Louis, Mo., on November 12, 1891, and received the degree of Bachelor of Science in electrical engineering from the University of Texas in 1914. He received a Master of Science degree from the University of Illinois in 1917, having earned a Research Fellowship from the University. Mr. Fritz first became associated with the Bell Telephone System in 1917, when he was a student engineer for the Bell Telephone Company of Pennsylvania. During the First World War, Mr. Fritz was a Second Lieutenant in the Artillery Corps, Army of the United States, and in 1919 accepted a position as Transmission Engineer with the Southwestern Bell Telephone Company, Dallas, Tex. In 1921 Mr. Fritz joined the Southwestern Bell Telephone Company, St. Louis, Mo., as a Transmission Engineer and reached his present position as Chief Engineer in 1947, after a series of promotions. Mr. Fritz was Chairman of the St. Louis Section from 1936 to 1937 and Secretary of the Southwest District from 1933 to 1934. He also was on the Communications Committee from 1946 to 1948 and is a member of Tau Beta Pi, Sigma Xi, and the St. Louis Engineers' Club.

John A. McDonald (A '21, M '39), Superintendent, Service Shop, General Electric Company, Salt Lake City, Utah, has been nominated to serve the Institute as Vice-President representing the North West District (number 9). Mr. McDonald was born on July 13, 1890, in Sydney, Nova Scotia, Canada, and studied for two years at the University of Liverpool. He also took extension courses from the University of Utah. In 1910, he began his industrial career as an electrician in the maintenance department of the Dominion Iron and Steel Company, Sydney, remaining with the company until 1912, when he secured a position with the United States Steel Company, Gary, Ind., as electrician and armature winder. From 1913 to 1914, Mr. McDonald worked as a foreman, Electrical Repair Department, for the International Smelting and Refining Company, Toelle, Utah, and later in 1914, accepted a similar position with the Capital Electric Company, Salt Lake City, Utah. During World War I, Mr. McDonald was a Second Lieutenant in the Ordnance Department of the Army of the United States, and returned to the Capital Electric Company upon completion of his military service. He remained with the Capital Electric Company until 1927, when he became associated with the General Electric Company, Salt Lake City, Utah, in his present capacity. Mr. McDonald was Chairman of the Utah Section from 1938 to 1939 and Secretary of the Utah Section from 1940 to 1949. Mr. McDonald's society memberships include the American Ordnance Association, the Utah Society of Professional Engineers, the National Association of Power Engineers, and Utah State Board of Engineering Examiners.

Siegfried, Dewars, Barrett, Nominated for Directorships

Victor Siegfried (A '32, M '38), Chief Research Engineer, Research and Development Laboratory, Electrical Cable Works, American Steel and Wire Company, Worcester, Mass., has been nominated to serve on the AIEE Board of Directors. He was born in Seattle, Wash., on December 13, 1909, and received the degree of Bachelor of Arts (1930) from Leland Stanford Junior University and the degree of Electrical Engineer (1932). Subsequently he was a graduate student at Harvard University and became an instructor in electrical engineering at Worcester Polytechnic Institute in 1933. In 1937 Mr. Siegfried was made an Assistant Professor, and during the summers of 1937 and 1940, he was employed in the high-voltage engineering laboratory of the General Electric Company, Pittsfield, Mass. He joined the American Steel and Wire Company in his present position in 1944. Since 1948, Mr. Siegfried has been Vice-President representing the North Eastern District, a Director of the Institute, and a member of the Industry Co-ordinating, Edison Medal, and Finance Committees. He is serving the Institute on the Mining and Metal Industry Committee and has been a member of the Membership Committee (1940–43) and the Sections Committee (1947–48). Mr. Siegfried was Secretary of the North Eastern District (1943–48), Chairman of the Worcester Section (1937–38), and a Student Branch Counselor (1939–41, 1942–44). He has written several AIEE papers and discussions on electric machinery and controls, and on electric cables. His society memberships include the American Society for Testing Materials, the American Chemical Society, the National Research Council Conference on Electrical Insulation, American Society for Engineering Education, American Association for the Advancement of Science, Worcester Engineering Society, Sigma Xi, and Eta Kappa Nu.

Allen Guthrie Dewars (A '17, M '27, F '44), Manager, System Planning, Operating Department, Northern States Power Company, Minneapolis, Minn., has been nominated to serve on the AIEE Board of Directors. Mr. Dewars was born on August 22, 1892, in Minneapolis, Minn., and received the degrees of Bachelor of Science (1913) and Electrical Engineer (1914) from the University of Minnesota. In 1914 he entered the employ of the St. Paul (Minn.) Gas Light Company, as apprentice engineer and in 1916 was advanced to the grade of Distribution Engineer in the Electrical Department of the company. He served with the Army of the United States in France and Germany from 1917 to 1919 and returned to the St. Paul Gas Light Company in 1919 as Assistant Superintendent of Distribution. Mr. Dewars was promoted to the position of Superintendent of his department in 1925 and the following year, when the company was absorbed by the Northern States Power Company, he assisted in consolidating the electrical properties of the two companies in St. Paul. In 1929, he was transferred to Northern States Power Company headquarters in Minneapolis and advanced in position with the company, attaining his present position as Manager, System Planning Department, in 1940. Mr. Dewars was a Director of the AIEE from 1942 to 1944 and, at the same time, was Vice-President representing the Great Lakes District (number 5). He served as Secretary of the Great Lakes District for 18 years prior to 1942 and is a Past-Chairman of the Minnesota Section. Mr. Dewars has been a member of the System Engineering Committee since 1948 and has also served on the following committees: Special Committee on Dues and Related Matters (1936–37); Production and Application of Light (1942–46); Instruments and Measurements (1943–44); and Special Committee on District Boundaries (1943–44). He is a member of the Engineers' Club of Minneapolis.

Walter J. Barrett (M '36, F '50), Electrical Co-ordination Engineer, New Jersey Bell Telephone Company, Newark, N. J., has been renominated to serve on the AIEE Board of Directors. Mr. Barrett was born in Brooklyn, N. Y., on January 10, 1899, and was graduated from the Polytechnic Institute of Brooklyn in 1920 with a Bachelor of Science degree in electrical engineering. Upon graduation, he entered the employ of American Telephone and Telegraph Company, Department of Operation and Engineering, and in 1922, was transferred to the staff of the transmission engineer for the company. In 1930, Mr. Barrett became a Supervisor in the Engineering Department, New Jersey Bell Telephone Company, Newark, N. J., and worked in that capacity until his appointment as Electrical Co-ordination Engineer in 1943. Mr. Barrett is a Director of the Institute and is a member of the Sections Committee and the Finance Committee. He was Secretary of the New York Section from 1945 to 1946 and Chairman of the Section from 1947 to 1948. In 1948, Mr. Barrett was Secretary of the New York City District (number 3). He is a Director and Past Vice-President of the Polytechnic Institute of Brooklyn (N. Y.) Alumni Association and a member of Delta Kappa Pi and Tau Beta Pi.

C. F. Terrell (A '10, M '18, F '46, Member for Life), Vice-President, Puget Sound Power and Light Company, Seattle, Wash., has accepted the position of Executive Director for the Nebraska Public Power System. Mr. Terrell started his career in the operating department of the company in 1910 and became associated with the Light and Power Department, El Paso (Tex.) Electric Company in 1925 as General Superintendent. He worked in a similar capacity for the Tampa (Fla.) Electric Company, prior to holding the position of Operating Manager for the Gulf States Utility Company from 1928 to 1940. In 1940, Mr. Terrell returned to the Puget Sound Power and Light Company as Operating Manager and was elevated to the position of Vice-President in 1942. He is a Past Vice-President representing the North West District and is a member of the Electric Club of Washington and the Northwest Electric Light and Power Association. **A. L. Pollard** (M '40), General Superintendent of Operations for the Puget Company, has been appointed to the position of Operating Manager. Mr. Pollard has also

Victor Siegfried

A. G. Dewars

W. J. Barrett

had an outstanding career in the light and power industry. Prior to his employment as Superintendent of the Steam Division, Puget Sound Power and Light Company, in 1930, he held numerous engineering positions in the light and power industry. In 1932 he was made Assistant General Superintendent of the company's Central Division in Seattle and became General Superintendent, Steam Heat and Steam Generation, in 1935. The following year, Mr. Pollard was made General Superintendent of Light and Power for the entire company and has held the position of General Superintendent of Operations since 1945. Mr. Pollard is an active member of the Committee on Power Generation and is a Past-President of the Electric Club of Washington.

M. L. Manning (A '36, M '42, F '48), Chief Engineer, Kuhlman Electric Company, Bay City, Mich., has accepted a position as Development Engineer with the Pennsylvania Transformer Company, Canonsburg, Pa. Mr. Manning holds a Bachelor of Science degree from South Dakota State College as well as a Master of Science degree from the University of Pittsburgh (Pa.). He has also completed the required courses for a Doctor of Philosophy degree. Mr. Manning has done research engineering work with the Westinghouse Electric Corporation and has been an Associate Professor of Electrical Engineering at the Illinois Institute of Technology and Cornell University. He is a member of the Transformer Committee and his society affiliations include the International Conference on Large Electric High Tension Systems, the American Society of Engineering Education, and Sigma Tau. **Boris Volgovskoy** (A '42, M '47), Design Engineer, Pennsylvania Transformer Company, has been appointed Head of the company's Substation and Regulator Department. Mr. Volgovskoy is a graduate of the University of Cincinnati (Ohio), Class of 1926, and started his career as a Test Engineer for the Cincinnati Gas and Electrical Company. Prior to his association with the Pennsylvania Transformer Company, Mr. Volgovskoy was Section Engineer, Switchgear Division, with the Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

Joseph Slepian (A '17, F '27), Associate Director, Research Laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been awarded the honorary degree of Doctor of Science by the University of Leeds, London, England. The award will be officially presented on May 19, and will mark the second time that Dr. Slepian has been honored abroad. In 1939 he was made "Officier de L'Academie" in France. Recognized as one of the world's leading authorities on the electric arc, Dr. Slepian holds such outstanding scientific awards as the John Scott Medal, the Lamme Medal, the Edison Medal, and the Westinghouse Order of Merit. He was elected to the National Academy of Science in 1940 and last year was given the honorary degree of Doctor of Engineering by Case Institute of Technology. A prolific inventor, Dr. Slepian is especially noted for his development of the Autoclave lightning arrester, the De-ion circuit breaker, and the famous ignitron tube which is widely used for converting alternating current into direct current. Dr. Slepian is a member of the Committee on Basic Sciences.

J. H. Levis, Jr. (A '21), Assistant Chief Telephone Engineer, Stromberg-Carlson Company, Rochester, N. Y., has retired from active service and will remain with the company on a consulting basis. Mr. Levis entered the Stromberg-Carlson Company's installation department in 1903, went into the engineering department the following year, and was transferred to the switchboard department in 1905. Five years later, he returned to the engineering department and was placed on the development of circuits and equipment. Mr. Levis holds many patents in the field of manual switchboards and automatic equipment, and he is credited with having increased efficiency to the extent that manual telephone operators could handle one-third more calls. In 1940, on the 150th anniversary of the United States Patent Office, he was given a "Modern Pioneer of America" award by Dr. Karl T. Compton, who was then president of the Massachusetts Institute of Technology.

Harold Chestnut (A '41, M '48), Engineer, Aeronautics Division and Ordnance Systems Division, General Electric Company, Schenectady, N. Y., has been awarded first prize in the Industry Class of the AIEE prizes together with R. W. Mayer. The award was given for their paper on "Comparison of Steady-State and Transient Performance of Servomechanisms." The paper is from material prepared for a book on servomechanisms by the two men, which will be published in the spring. The work represents a great advance in the study of servomechanisms and is particularly useful for design work. Mr. Chestnut is a member of Tau Beta Pi, Eta Kappa Nu, and Sigma Xi.

F. E. Bodine (A '43), Pacific Coast Maintenance Manager, Westinghouse Electric Corporation, San Francisco, Calif., has been named Assistant Central Station Manager of the Pacific Coast District. Mr. Bodine joined Westinghouse in 1926 as a graduate student and was transferred to the Salt Lake City, Utah, office as a salesman in 1928, attaining the position of sales manager in 1941. He was made Pacific Coast Maintenance Manager in 1944. He is a Director of the San Francisco Sales Managers Association, a member of the Electric Club of San Francisco, and the Domestic Trade Committee, San Francisco Chamber of Commerce.

O. O. Rae (A '26), Assistant District Manager, Southeastern Central Station and Transportation Division, Westinghouse Electric Corporation, Atlanta, Ga., has been appointed Manager of the company's Southeastern District. Mr. Rae joined Westinghouse after his graduation from Georgia Institute of Technology in 1919, and was assigned to the company's merchandise sales department. In 1922 he was transferred to the Central Station Sales Organization of the Southeastern District in Atlanta. Mr. Rae was promoted to Central Station Manager of the district in 1934. He is a member of The American Society of Mechanical Engineers and the Industry Association.

A. J. Ackerman (M '49), Director and Vice-President in charge of Hydroelectric Construction of the Brazilian Technical Service and Management Company, Sao Paulo, Brazil, has been elected Director and Vice-President in charge of Engineering of Canadian-Brazilian Services Limited, Toronto, Ontario, Canada. Both these companies are subsidiaries of the Brazilian Traction, Light and Power Company of Toronto which, through operating subsidiary companies, supplies electric power to the cities of Rio de Janeiro, Sao Paulo, Santos, and the adjacent region in Brazil.

A. E. Thiessen (M '41), Vice-President, General Radio Corporation, Cambridge, Mass., has been elected a Director of the company. He is replacing **Melville Eastham** (A '22, M '26, F '46), who has retired. Mr. Eastham founded the General Radio Company in 1915 and was its President from that year until 1944. Since 1944 he has held the title of Chief Engineer, from which post he also has retired. Mr. Eastham is a member of the Special Communication Applications Committee.

D. M. Berges (M '50), Chief Engineer, Electrical Section, Pesco Products Division, Borg-Warner Corporation, Chicago, Ill., has been appointed Chief Engineer of the new Pesco Products plant in Bedford, Ohio. In assuming his new position, Mr. Berges will be in charge of all the research facilities which are a part of the new plant. He is a graduate Mechanical Engineer from Stevens Institute of Technology in Hoboken, N. J., and he has been directly associated with the design, manufacture, and sale of aircraft accessories since 1931.

J. E. Ryan (M '46), Engineer in Charge, Control Division Laboratory, General Electric Company, Schenectady, N. Y., and **C. P. Hayes** (A '41), Division Engineer, Ballast Division, Specialty Transformer and Ballast Divisions, General Electric Company, have been appointed Staff Assistants to the Manager of Engineering, Small Apparatus Divisions. Mr. Ryan is a member of the Industrial Control Committees and Mr. Hayes is a member of the Committee on Production and Application of Light.

N. A. Williams (A '39), Associate Professor of Electrical Engineering and Acting Chairman of the Department of Electrical Engineering, University of Manitoba, Canada, has been promoted to the rank of Professor and also made Chairman of the Department of Electrical Engineering. Mr. Williams is a member of the Association of Professional Engineers of the Province of Manitoba and a Corporate Member of the Engineering Institute of Canada.

W. H. Schwalbert (A '37, M '48), Investigation Engineer, The Toledo Edison Company, Toledo, Ohio, has been named System Planning Engineer. Mr. Schwalbert started with the Edison company in 1936 and has successively been Assistant to the Superintendent of Electric Distribution and a Construction Engineer. As Investigation Engineer, he planned and supervised various major additions to the Toledo Edison Company's physical plant.

L. E. St. John (M '47), Chief Engineer, Ansco Division, General Aniline and Film Corporation, and **N. L. Platt** (A '43), Power Engineer, General Aniline and Film Corporation, have opened offices in Binghamton, N. Y., under the name of St. John and Platt as consultants in the fields of mechanical and electrical engineering. Mr. Platt is a member of the General Industry Applications Committee.

S. J. McDowell (A '46), Development Ceramic Engineer, American Lava Corporation, Philadelphia, Pa., has joined the company's metropolitan office in Newark, N. J. He is the author of many published technical papers on ceramics and is President of the New Jersey Ceramic Association.

G. P. Cardwell (A '41, M '49), Consulting and Application Engineer, Westinghouse Electric Corporation, Detroit, Mich., has joined the Westinghouse Electric Supply Company in York, Pa., as an Application Engineer.

OBITUARY • • • • • •

William Noble Dickinson (F '35, Member for Life), Research Engineer of Rockville Centre, N. Y., died January 26, 1950. Born in New York, N. Y., on June 20, 1872, Mr. Dickinson attended Pratt Institute and the Polytechnic Institute of Brooklyn. He became associated with the Elektron Manufacturing Company in 1889 as a Foreman and rose to the position of Vice-President. After the Elecktron Manufacturing Company was absorbed by the Otis Elevator Company, he took charge of the company's foreign business and from 1920 to 1926 was a consulting engineer for the firm. Mr. Dickinson started his own research laboratory in 1926, pioneering in the development of the electric elevator, and from 1930 to 1935, originated and developed new principle controls and signals for electromechanical equipment, many of which he patented. He was a member of The American Society of Mechanical Engineers and a Past-President of the New York Electrical Society.

MEMBERSHIP • • • •

Recommended for Transfer

The Board of Examiners at its meeting of February 16, 1950, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To the Grade of Fellow

Baughn, E., elec. engr., The Washington Water Power Co., Spokane, Wash.
Brown, G. S., elec. engg. prof.; director, Servomechanisms Lab., Massachusetts Institute of Technology, Cambridge, Mass.
Corcoran, G. F., prof. & chairman, elec. engg. dept., Univ. of Maryland, College Park, Md.
Lachicotte, F. W., elec. engr.; chg. distribution, Duke Power Co., Charlotte, N. C.
Lee, H. R., regional power mgr., Bureau of Reclamation, Denver, Colo.
LeVee, C. H., mgr., utility sales, wire & cable dept., U. S. Rubber Co., New York, N. Y.
Mueller, G. V., prof. elec. engg., Purdue Univ., West Lafayette, Ind.
Robinson, H. B., vice pres. chg. of operations & engg., Carolina Power & Light Co., Raleigh, N. C.
Uhr, I. A., mgr., San Antonio office, General Electric Co., San Antonio, Tex.

9 to grade of Fellow

To the Grade of Member

Adams, H. W., cable engr., Reynolds Metals Co., Louisville, Ky.
Alimansky, M. I., asst. to mgr. of engg., General Electric Co., Pittsfield, Mass.
Balacek, F. P., member of technical staff, Bell Telephone Labs., Inc., New York, N. Y.
Bardsley, R. V., northwestern div. engr., Sylvania Electric Products, Inc., Seattle, Wash.
Benish, J., asst. prof., Texas A & M College, College Station, Tex.
Bernthal, V. O., div. operating supt., Public Service Co. of Northern Ill., Glencoe, Ill.
Blomquist, E., senior supervisory design engr., Public Service Co. of Northern Ill., Chicago, Ill.
Bonds, E. R., chief elec. engr., Cleveland Electric Co., Inc., Atlanta, Ga.
Dorsey, O. B., design engr., Public Service Co. of Northern Ill., Chicago, Ill.
Dovi, S. F., specialist, New York Shipbuilding Corp., Camden, N. J.
Eddy, H. T., div. engr., Public Service Co. of Northern Ill., Maywood, Ill.
Farmer, G. E., communication & signal engr., Tennessee Valley Authority, Chattanooga, Tenn.
Feher, L. H. A., electronics engr., Naval Research Lab., Washington, D. C.
Feldman, K., chief elec. engr., Compania Anonima Venezolana Lummus, Maracaibo, Venezuela
Ferguson, A. F., cperating supt., Hydro-Electric Power Comm. of Ontario, London, Ontario, Canada
Ferguson, J. G., member of technical staff, Bell Telephone Labs., Inc., New York, N. Y.
Gaylord, E. H., head, design section, Bureau of Reclamation, Casper, Wyo.
Gute, L. R., engr., General Electric Co., Lynn, Mass.
Hartley, J. C., application engr., General Electric Co., Schenectady, N. Y.
Heagler, E. F., elec. engr., Moloney Electric Co., St. Louis, Mo.
Hitt, J. C., elec. engr., Jackson & Moreland, Boston, Mass.
Ibata. R. M., asst. prof., elec. engg., Univ. of Nebraska, Lincoln, Nebr.
Jarvis, T. F., elec. engr., Warsaw Elevator Co., Warsaw, N. Y.
Kimble, J., asst. chief engr., Rhodes Lewis Co., Engineers, Los Angeles, Calif.
Kraybill, V. H., supervising instrument engr., Public Service Co. of Northern Ill., Maywood, Ill.
Loughran, J. A., development engr., General Electric Co., Schenectady, N. Y.
Mable, W. H., senior design engr., Duquesne Light Co., Pittsburgh, Pa.
Maury, T. E., supervising engr., Western United Gas & Electric Co., Aurora, Ill.
McCoy, J. H., instrument engr., Reynolds Metals Co., Sheffield, Ala.
McGee, H. S., starting engr., Public Service Co. of Northern Ill., Maywood, Ill.
Mendelson, S. I., elec. engg. designer, The H. K. Ferguson Co., Cleveland, Ohio
Moats, W. L., application engr., Westinghouse Electric Corp., Salt Lake City, Utah
Olney, F. D., design engr., General Electric Co., Ft. Wayne, Ind.
Olson, S. A., protection engr., Public Service Co. of Northern Ill., Chicago, Ill.
Otto, H. W., supt. of power, Public Service Co. of Northern Ill., Maywood, Ill.
Parham, W. L., chief system operator, Aluminum Co. of America, Alcoa, Tenn.
Pippenger, E. E., supervisory engr., Public Service Co. of Northern Ill., Chicago, Ill.
Ragazzini, J. R., assoc. prof. of elec. engg., Columbia Univ., New York, N. Y.
Rich, F. W., engr., Commonwealth Services, Inc., Jackson, Mich.
Shaw, R. W., asst. engr., Omaha Public Power District, Omaha, Nebr.
Snadyc, A. M., Jr., electronics engr., material lab., N. Y. Naval Shipyard, Brooklyn, N. Y.
Sumpter, P. B., elec. design engr., Ebasco International Corp., New York, N. Y.
Tilden, W. C., elec. engr. III, Tennessee Valley Authority, Johnson City, Tenn.
Tsao, T. C., Ebasco International Corp., New York, N. Y.
Wear, E. G., station design engr., Public Service Co. of Northern Ill., Chicago, Ill.
Wendt, R. L., senior project engr., Sperry Gyroscope Co., Great Neck, N. Y.
White, A. B., project engr., Western Electric Co., Clarksville, Tenn.
Whysong, J. L., engr., system dev. sec., Public Service Co. of Northern Ill., Chicago, Ill.
Wiegand, D. E., senior physicist, Armour Research Foundation, Chicago, Ill.
Wilkerson, S. C., supt., Alcoa Power Div., Calderwood, Tenn.
Williams, A. L., dis. & trans. design engr., Los Angeles Dept. of Water & Power, Los Angeles, Calif.

51 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should so notify the Secretary before April 25, 1950, or June 25, 1950, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Fellow

Brown, W. J., 512 Marshall Building, Cleveland, Ohio

1 to grade of Fellow

To Grade of Member

Ascione, R., Western Union Tel. Co., New York, N. Y.
Baughman, G. L., Havens & Emerson, Cleveland, Ohio
Blokland, J. A., Shell Caribbean Petroleum Co., La Concepcion, Venezuela, South America
Bossart, P. N. (re-election), Union Switch & Signal Co., Pittsburgh, Pa.
Brandow, G. W., Salt River Power Dist., Phoenix, Ariz.
Briggs, W. G., I-T-E Circuit Breaker Co., Chicago, Ill.
Chatto, H. M., General Elec. Co., Medford, Mass.
Davis, H. F., Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.
Dawson, J. A., Ohio Bell Tel. Co., Columbus, Ohio
Duncan, J. R., Holsclaw Equipment Co., Charleston, W. Va.
Eveleth, L. N., Bureau of Yards & Docks, Washington, D. C.
Farr, H. K., General Elec. Co., Pittsfield, Mass.
Fay, A. H., Dictograph Products, Inc., Jamaica, N. Y.
Ferguson, F. H., Naval Research Lab., Washington, D. C.
Friedberg, M. R., Ward Products Corp., Cleveland, Ohio
Frobe, R. W., Arkansas Power & Light Co., Hot Springs, Ark.
Goddard, K. R., Thomas & Hutton, Savannah, Ga.
Granneman, A. H., Fluor Corp., Los Angeles, Calif.
Gunter, F. B., Westinghouse Elec. Corp., Baltimore, Md.
Henry, W. R., Northwest Industries Ltd., Edmonton, Alberta, Canada
Hoff, N. S., Bell Tel. Co., of Pennsylvania, Pittsburgh, Pa.
Holeman, T., Allen & Hoshall, Memphis, Tenn.
Howley, J. T., Dominion Tar & Chem. Co., Ltd., Montreal, Quebec, Canada
Hutchinson, H. C., Public Housing Admin., New York, N. Y.
Kenny, T. A., The Esterline-Angus Co., Inc., Summit, N. J.
Lieber, G. R., Shreveport Armature & Elec. Works, Shreveport, La.
Little, H. B., Toronto Hydro-Elec. System, Toronto, Ontario, Canada
Lopez, A. F., Penn State College, State College, Pa.
Lovewell, K. M., Potomac Elec. Power Co., Washington, D. C.
Massie, L. E., Electrical Products Corp., Los Angeles, Calif.
McWhorter, K., McWhorter, Robinson & Moody, Staunton, Va.
Morgan, F. B., N. Y., State Elec. & Gas Corp., Binghampton, N. Y.
Oltrogge, A. R., General Elec. Co., Schenectady, N. Y.
Orton, L. S., Box 1644, Anchorage, Alaska
Parsons, M., United Engineers & Constructors, Inc., Philadelphia, Pa.
Patel, R. R., Messrs. Josts Engg. Co., Ltd., Bombay, India
Reinbold, R. E., Central Arizona Light & Power Co., Phoenix, Ariz.
Rietz, G. A., General Elec. Co., Schenectady, N. Y.
Santuari, E., Societa Edison, Milano, Italy
Schwerer, F. C., West Penn Power Co., Ridgway, Pa.
Singh, S., Escorts (Agents) Ltd., New Delhi, India
Stevens, G. D. (re-election), Consumers Power Co., Jackson, Mich.
Wagner, C. B., General Elec. Co., Richland, Wash.
Wilhite, J. W., Corps of Engineers, Mountain Home, Ark.

44 to grade of Member

OF CURRENT INTEREST

Complete Electric Systems for Large Aircraft Can Be Tested in New Boeing Laboratory

A new electrical laboratory, so complete it can duplicate for testing purposes the entire electric system of large multiengined aircraft, has been put into operation at Seattle, Wash., by the Boeing Airplane Company.

The new Boeing laboratory provides facilities to do almost all testing of a new airplane's electric systems, generators, alternators, motors, switches, and wiring as a complete unit prior to construction of the actual airplane. The result is a saving of time, money, and effort in the development of any new aircraft type.

The laboratory's test setup for the Boeing *B-47* Stratojet, as an example, has been tested in the new facility. Fastened upon vertical metal racks, every wire, switch, motor, gauge, and other component of the bomber's electric system is reproduced in the laboratory.

A battery of three 500-horsepower gasoline engines provides flexible power needs for the test center. A maximum of 840 kw of power can be generated. Voltages may be varied from 100 to 450 volts, and amperage up to 3,300, depending upon the nature of the loads they must carry.

The engine room, situated at one corner of the new electrical laboratory, also contains a control panel from which all three engines are initially started. With suitable adapters, as many as 12 airplane power generators may be tested simultaneously—duplicating generator loads on a 12-engine airplane.

Another part of the new laboratory is a shielded room, free from static, where radio research and development are conducted. Altogether, the new facility has 14 specialized working centers, each doing a particular type of electrical research. Each has convenient access to direct voltages ranging from six to 120 volts; 400-cycle 115- and 200-volt alternating current; and 115- to 480-volt, 60-cycle a-c power. Through various transfer circuits, the different centers of the laboratory can be connected directly to one another.

One project now under way is an Air Force-sponsored program to explore fully the possibilities of using 120-volt d-c systems in aircraft.

This is the recording station of oscillographs, which make a split-second record of every function of the entire electric system of large multiengined aircraft, and is a small part of the Boeing Airplane Company's new electrical test laboratory. The laboratory provides facilities to do almost all testing of a new airplane's electric systems, generators, alternator, motors, switches, and wiring as a complete unit prior to construction of the actual airplane

K. B. McEachron Gives Lecture Before New York Electrical Society

On Friday evening, March 10, 1950, Dr. K. B. McEachron gave a popular lecture on lightning before the 636th meeting of the New York Electrical Society in the Western Union Auditorium. The meeting was presided over by H. P. Corwith, President of the society, who introduced the speaker.

By means of lantern slides, Dr. McEachron illustrated what the lightning stroke looks like in space. During the investigation, 1936–1946, pictures were made with cameras trained on the Empire State Building from different locations which were synchronized with oscillograph records. A special camera with a stationary and a revolving lens was used. The work represented the first time that anyone had obtained an oscillographic record and a photographic record of the same stroke. In cases of tall structures, 80 per cent of the strokes were from building to cloud. With storms coming from the west and south west across the Hudson, it was also explained why the Empire State took more strokes than the Chrysler Building.

An interesting photograph taken by a man in the Consolidated Edison Company of New York, Inc., on one of the Jersey beaches clearly showed three upward streamers and, as Dr. McEachron explained, provided a missing link in the data on stroke phenomena. Curves were also shown with data taken by others by different means such as that by McCann, and Lewis and Foust, which showed a fairly close correlation.

With regard to airplanes, Dr. McEachron showed slides of small burns on parts of airplanes, and he stated that there were no known cases of fatal accidents to airplanes as the result of lightning.

With regard to protection against lightning, Doctor McEachron showed how the cone of protection was demonstrated in the laboratory with a steel plate on the floor, one electrode overhead, and another movable electrode off to the side offering about a 45 degree angle of protection. He also illustrated how a Quonset Hut or munition dump could be protected by an overhead ground wire and buried counterpoise; in the case of transformers on a line he emphasized the importance of keeping the lightning arrester or protective device as close as possible to the transformer. In the cases of structures such as silos and tank farms, the importance of bonding all foreign pipes which enter them was illustrated.

In the Pittsfield area only about one in 4,000 homes are struck per year and Dr. McEachron pointed out that in an automobile one is just as safe from lightning as in a furnace or a refrigerator. Slides were shown of the damage to houses, the explosive effect of gases from lightning discharge, and the importance of good grounding, as well as the damage to cattle in the open and to cows which took shelter under a tree.

At the conclusion of the lecture Dr. McEachron answered questions and explained how the aluminum cone arrester led to the development of the thyrite lightning arrester.

American Gage Merges With Simpson Electric

The American Gage and Machine Company has announced their merger with the Simpson Electric Company, manufacturer of electric measuring instruments and radio and television test equipment. Both companies are located in Chicago, Ill.

Ray Simpson, founder of the Jewell Electrical Instrument Company, Simpson Optical Company, and the former Simpson Electric Company, will remain as Chairman of the Simpson Electric Division. Wallace E. Carroll, founder of the parent company, will remain as President.

A. W. Hull, Magnetron Inventor, Retires From General Electric

Dr. Albert W. Hull, assistant director of the General Electric Research Laboratory, who has been credited with the invention of more types of electron tubes than any other man, retired recently.

One of the tubes invented by Dr. Hull was the magnetron, his basic invention having been made in 1921. Later it was modified and improved by scientists in many countries, and during World War II formed the heart of short-wave radar. Magnetrons are now being applied for quick heating of plastics and other materials in many industrial processes.

He also made basic inventions in the screen-grid tube, which made possible modern radio and television receivers. The thyratron is another Hull invention. This tube, employed for automatic control of electric welding and many other industrial processes, is used in addition to regulate the lighting in Radio City Music Hall in New York, N. Y. His latest invention, relating to the caesium rectifier for converting alternating current to direct current, is not yet in commercial production.

Dr. Hull was born at Southington, Conn., and attended Yale University, graduating in 1905. Continuing in postgraduate studies, he received the degree of Doctor of Philosophy from Yale University in 1909. After this he taught physics, first as instructor, then assistant professor, at Worcester Polytechnic Institute, before he accepted a position as a research physicist in the General Electric Research Laboratory in 1914. In 1928 he was made Assistant Director of the laboratory.

Up to the first of this year Dr. Hull has been awarded almost 100 patents. He served as President of the American Physical Society in 1942 and is a member of the National Academy of Sciences, Phi Beta Kappa, and Sigma Xi. He is a Fellow of the American Physical Society and the Institute of Radio Engineers.

NBS Receives Memory Units for Use in Electronic Computer

The National Bureau of Standards has received the first of three Technitrol Memory Units to be used in the latest type of large-scale electronic computer developed jointly by funds of the Air Comptroller, Department of the Army, and NBS. This automatic brain will remember for later recall any sequence of facts or figures once they have been placed on it.

The Memory Unit is based on the principle of the mercury delay line originally conceived at the University of Pennsylvania. It has reached its latest development through the joint efforts of the staff of the Electronic Computer Section of NBS under the direction of Dr. S. N. Alexander and the engineers of Technitrol Engineering Company, under the direction of Gordon Palmer, Jr., Vice-President of the company.

This latest development in computers is known as the NBS Interim Computer. In addition to contemplated work in processing the 1950 census figures, the Interim Computer will be studied in an effort to develop new and better computers for government and commercial use. It will also be utilized for the solution of many of the scientific problems that arise in the normal work of the Bureau.

Future Meetings of Other Societies

American Chemical Society. 117th National Meeting. April 9–13, 1950, Detroit, Mich.; April 16–20, 1950, Philadelphia, Pa. Chicago Section—Sixth National Chemical Exposition. September 5–9, 1950, Chicago Coliseum, Chicago, Ill.

American Electroplaters' Society. Fourth International Electrodeposition Conference. June 12–16, 1950, Statler Hotel, Boston, Mass.

American Society for Quality Control. Conference on Cost Reduction Through Statistical Quality Control. April 29, 1950, New York University College of Engineering. Fourth National Convention. June 1–2, 1950, Milwaukee, Wis.

American Society for Testing Materials. 53d Annual Meeting and 9th Exhibit of Testing Apparatus and Equipment. June 26–30, 1950, Atlantic City, N. J.

American Society of Mechanical Engineers. Spring Meeting. April 12–14, 1950, Statler Hotel, Washington, D. C.

American Society of Tool Engineers. 18th Annual Meeting andIndustrial Cost-Cutting Exposition. April 10–14, 1950, Convention Hall Buildings, Philadelphia, Pa.

Armed Forces Communications Association. 1950 Annual Meeting. May 12, 1950, New York, N. Y.; May 13, 1950, Fort Monmouth, N. J.

British Industries Fair. Engineering Section. May 8–19, 1950, Castle Bromwich, Birmingham, England.

Institute of the Aeronautical Sciences. Seventh Annual Personal Aircraft Meeting. May 19–20, 1950, Lassen Hotel, Wichita, Kans. Annual Summer Meeting. July 12–14, 1950, IAS Western Headquarters Building, Los Angeles, Calif.

Instrument Society of America. 1950 Instrument Conference and Exhibit. September 18–22, 1950, Memorial Auditorium, Buffalo, N. Y.

Midwest Power Conference. April 5–7, 1950, Sherman Hotel, Chicago, Ill.

National Association of Broadcasters. Fourth Annual Engineering Conference. April 12–15, 1950, Stevens Hotel, Chicago, Ill.

National Association of Corrosion Engineers. Sixth Annual Conference. April 4–7, 1950, Jefferson Hotel, St. Louis, Mo. Inter-Society Corrosion Committee. April 1–7, 1950, Jefferson Hotel, St. Louis, Mo.

National Electrical Manufacturers Association. March 13–16, 1950, Edgewater Beach Hotel, Chicago, Ill.

National Petroleum Association. April 12–14, 1950, Hotel Cleveland, Cleveland, Ohio.

New Jersey Society of Professional Engineers. Annual Convention. April 14–15, 1950, Essex House, Newark, N. J.

Refrigeration Manufacturers of America—Refrigeration Service Engineers Society. 1950 Midwest Refrigeration and Air Conditioning Educational Exhibit and Conference. May 25–28, 1950, New Hotel Jefferson, St. Louis, Mo.

Engineering Foundation Stirs Broad Advances in Engineering

Sponsorship and grants of $42,500 by Engineering Foundation to 12 projects in fundamental research in the engineering sciences and to two projects in advancing the engineering profession stimulated contributions by industry and universities of $642,800 to these projects for the fiscal year ending September 30, 1949, according to the annual report of the Foundation.

Notable among the current Foundation projects are the three councils (on riveted and bolted structural joints, on the properties of columns, and on the characteristics of reinforced concrete) sponsored by the American Society of Civil Engineers. These councils were established because of a lack of precise data for design formulas and specifications and all three are showing exceptional progress.

The oldest of the three, on riveted and bolted joints, has six research projects under way and the results should soon be of value in the design of new railway and highway bridges, and in strengthening older bridges now subject to steadily increasing traffic loads and speeds. One important conclusion already available is that a bolted joint has considerably higher resistance to failure by fatigue than a similar joint fabricated with either hot- or cold-driven rivets.

Prominent among the projects sponsored by the other societies are studies on the properties of metals at high and low temperatures, on the plastic flow of metals, and on the properties of petroleum-base and synthetic lubricants and the correlation of these properties with the behavior of the lubricant in various types of machines.

Of the Foundation projects for the advancement of the engineering profession, the Engineers' Council for Professional Development has recently had an enviable record of achievement. It has studied and approved 314 engineering curricula in 74 colleges and universities and has started to survey South American universities with the object of recommending standards for the curricula of these institutions. It has also developed a test for determining the aptitudes that are essential, or at least desirable, if a high-school graduate is to be successful in a college engineering course and career.

New England Radio Engineering Meeting to Be Held in Boston

An outstanding program of technical papers will be offered to radio engineers attending the 1950 New England Radio Engineering Meeting to be held at the Somerset Hotel, in Boston, Mass., on Saturday, April 15. For the past three years these one-day conference-meetings, sponsored by the North Atlantic Region of the Institute of Radio Engineers, have been highly successful, enabling engineers to keep abreast of latest progress through technical papers and manufacturers' exhibits without taking too much time from their regular activities. In keeping with New England's many expanded educational and research facilities, the theme of the April 15 meeting is "Progress Through Research."

In addition to a morning and afternoon technical program, those attending the April

15 meeting in Boston will have opportunity to visit the television facilities of *WBZ* and to inspect the toll dialing equipment of the New England Telephone and Telegraph Company. Members of the Boston and Connecticut Valley Sections, comprising the North Atlantic Region of the IRE, will have opportunity to discuss their mutual problems under the guidance of Herbert J. Reich, Regional Director of the IRE for the New England area.

Lawrence B. Grew, engineer for the Southern New England Telephone Company, and Chairman of the Connecticut Valley Section, will conduct the morning technical session. Hermon H. Scott, President of H. H. Scott, Incorporated, and Chairman of the Boston Section, will preside at the afternoon technical session.

Although the New England Radio Engineering Meeting is planned especially for radio engineers in the New England area, a cordial invitation is extended to all interested persons. Material for advance registration will be mailed to all members of the IRE in New England. Nonmembers and exhibitors may obtain further information from W. M. Brodhead, General Chairman, 131 Clarendon Street, Boston, Mass.

Creation of a National Policy on Water Resources Advocated

A temporary Water Resources Policy Commission to study the problem of adequate conservation and development of our national water resources and to evolve a policy was appointed by executive order of President Truman just before Congress convened this year. Earlier, the Engineers' Panel on National Water Policy had been instructed to take all proper steps available to bring about the creation of a Commission which would review present water resources policies and make recommendations to the Congress for revision and restatement.

The Engineers Joint Council, at its meeting on January 20, approved a program for outlining the engineering profession's conception of the elements of a sound national water policy. These concepts, when developed, will be presented to the President's temporary Water Resources Policy Commission. Under the program, the Water Policy Panel is instructed to set up task committees covering various subdivisions of the fields of water conservation, development, and utilization. Members of the profession experienced in these fields are to be sought out through each of the five constituent societies and asked to accept service on the committees as a professional contribution to an important national public matter.

The recommendations of the task committees, after review and co-ordination, will be formally transmitted to the temporary Presidential Commission. Since the President has directed this temporary Commission to complete its work by December 1, 1950, it is evident that to be of service, recommendations from the engineering profession should be transmitted to it by July 1, if possible.

Prompt action by the Engineers Joint Council Panel is planned in forming the various task committees. The Panel is now engaged in setting up the number of committees by subject and scope, and in outlining their definite fields of responsibility. Invitations for committee service are expected to go to selected members of the five national societies within the next month.

Until now, serious consideration of the engineers' interest in revision and clarification of water policy appears to have been confined to the committees of the Engineers Joint Council, of the American Society of Civil Engineers, and of specialized societies such as the American Water Works Association and the National Water Conservation Conference. The present Engineers Joint Council project envisages collaboration by a large number of members of its five national engineering societies.

New G-E Quality Control Indicator

This new instrument, called the Quality Control Indicator, keeps a continuous automatic check on reject rates in manufacturing operations and makes possible the rapid location and remedy of abnormal production difficulties. The indicator uses a signalling device to count the number of articles produced. Every time an inspector rejects a unit, he pushes a button, and this causes a change of reading on the indicating meter. When the reject level exceeds a predetermined rate, the needle on the meter moves from the green half of the scale to a red half, indicating that corrective action is needed. The equipment consists of two units: a "totalizer" and a "characteristic analyzer." Reject levels up to ten per cent may be monitored

Army Signal Corps Develops New Transmission Line

A revolutionary telephone and television transmission line having many industrial and military uses was announced by the United States Army Signal Corps at the annual convention of the Institute of Radio Engineers in New York, N. Y.

The line, which is simple, highly efficient, and costs little to manufacture, has been named "G-string" after the initials of the inventor, Dr. Georg Goubau of the Signal Corps Engineering Laboratories, Fort Monmouth, N. J. It is a single wire with special insulation and funnel-shaped terminals and promises to open up wholly new possibilities in microwaves and home television.

The Signal Corps expects the line to bring important improvements to radar operation and also, possibly, to replace coaxial cable, which is both intricate and expensive, for many applications. One immediate use of Dr. Goubau's "G-string" may be as an inexpensive means of distributing television programs to city homes on a "wired wireless" basis, which at present is prohibitively high in cost. It also may be possible to pipe television programs at relatively low cost to areas of the United States now out of television range.

The "G-string" also may make practical the development of a videophone, by which a telephone subscriber could go to his local exchange, pick up an instrument, and talk to a friend across the continent, and both parties could see each other. The new Signal Corps line could carry a hundred such videophone conversations simultaneously on a single wire, compared with the ability of today's single coaxial cable to carry only one.

Bell Telephone Laboratories Award Jewett Fellowships

Five young scientists were named recently by Bell Telephone Laboratories to receive the 1950–51 Frank B. Jewett postdoctoral fellowships. The awards, for research in the physical sciences, grant $3,000 to the recipient and $1,500 to the institution at which he chooses to do his research.

Winners of this year's awards are: Dr. James French, Massachusetts Institute of Technology; Dr. Ilse Lisl, Wellesley College; Robert Steiner, Harvard University; Dr. David Mann, University of Minnesota; and Dr. Roy Glauber, Institute for Advanced Study. Two of the winners are chemists, two are physicists, and one a mathematician.

Grants for the fellowships were established in 1944 by the American Telephone and Telegraph Company, upon the retirement of the late Dr. Jewett as Vice-President in charge of Development and Research. Since that time 33 fellowships have been awarded.

The fellowships are designed to stimulate and assist research in the fundamental physical sciences and particularly to provide the holders with opportunities for individual growth and development as creative scientists. Jewett fellows have conducted research at ten of the country's leading universities and institutes. Each recipient is free to select the institution at which he will do his research.

The fellowships are awarded on recommendation of a committee consisting of seven members of the technical staff of the company. Primary criteria are the demonstrated ability of the applicant, the fundamental importance of the problem he proposes to attack, and the likelihood of his growth as a scientist. The awards are postdoctoral and only scientists who have recently received doctor's degrees or who are about to receive them are normally considered.

MIT Announces Graduate Study and Staff Position Opportunities

Opportunities for graduate study and junior staff positions in teaching and research for the year 1950–51 in the department of electrical engineering at the Massachusetts Institute of Technology have been announced. Graduate programs leading to Master of Science (one year), Electrical Engineer (two years), and Doctor of Science or Doctor of Philosophy (three years) degrees are available in the department.

Broad research opportunities for graduate students are made possible by the many MIT laboratories affiliated with the department of electrical engineering. These include the Research Laboratory of Electronics, Servomechanisms Laboratory, High-Speed Digital Computer, Dynamic Analysis and Control Laboratory, Center of Analysis, Laboratory for Insulation Research, High-Voltage Laboratory, Synchrotron Laboratory, Network Analyzer, Stroboscopic Photographic Laboratory, and Acoustics Laboratory.

Appointments as full-time research assistants and associates will be made to some graduate students, and teaching assistants and instructors, to work in undergraduate laboratories concerned with electric machinery and measurements, electronics, communications, and acoustics, will also be needed. In both cases part-time graduate studies will be possible.

IRE Radio Show

ANTARA PRODUCTS
Polarad

A portion of the main floor of Grand Central Palace in New York, N. Y., during the Radio Show, March 6–9, where more than 250 exhibitors showed the latest communication and industrial electronic equipment. This show was a part of the annual convention of the Institute of Radio Engineers, at which approximately 17,000 were registered. The technical sessions were held in the Hotel Commodore

National Bureau of Standards Revising Thermocouple Tables

An extensive project is now under way at the National Bureau of Standards for revision of all the common thermocouple tables in order to take into account the recent changes in electrical units and in the International Temperature Scale. Present plans call for the publication during 1950 of eight tables giving the temperature-electromotive-force relations for platinum-platinum rhodium, chromel-alumel, and copper constantan thermocouples.

The temperature-electromotive-force tables for thermocouples previously issued by the Bureau have been widely used in science and industry, not only to convert thermocouple voltages into the equivalent measured temperatures, but also in the preparation of purchase specifications for thermocouple wire and in defining the relation between impressed electromotive-force and scale reading for pyrometers which indicate temperature directly. Recently, however, in accordance with international agreement, the Bureau adopted the absolute electrical units and began using the definitions of the new International Temperature Scale of 1948 both in its own research program and in calibrating instruments for other laboratories and industries. Revision of the thermocouple tables was then advisable in order to make them consistent with former usage.

In the preparation of the tables, emphasis is being placed on convenience for use. Thus, the explanatory text will be short, the numerals will be as large as practical, and the layout of pages and headings will be arranged to facilitate interpolation. The argument will be presented at one-tenth the interval given in the original tables. Inverse tables, formerly lacking, will also be included.

Each of the tables, together with its inverse, will be issued as an NBS Miscellaneous Publication and, when announced, will be available from the Superintendent of Documents, United States Government Printing Office.

Dr. Francis C. Frary Awarded Douglas Metallurgical Medal

Dr. Francis C. Frary, Director of Research, Aluminum Company of America, has been awarded the James Douglas Metallurgical Medal for 1950 by the American Institute of Mining and Metallurgical Engineers. The award was presented "for distinguished achievement in science and contribution to society by broadening the field of knowledge in all phases of the aluminum industry and for his notable success in directing a vast research project in this industry." The James Douglas Medal has been awarded only four times in the past ten years.

Among the many achievements of the medalist, two of the most outstanding include the production for the first time of very pure aluminum (99.99 per cent) by electrolytic refining, and the production of pure alumina by electrothermal processes. Dr. Frary holds many patents and is the author and coauthor of numerous books and papers in the fields of metallurgical and also of chemical research.

This high honor of the AIME adds to an impressive list of medals that Dr. Frary has received. He has previously been awarded the Gold Medal of the American Society for Metals, the Perkin Medal of the Society of Chemical Industry, the Acheson Gold Medal and Prize of The Electro-chemical Society, and also the Pittsburgh Award presented by the American Chemical Society, Pittsburgh Section.

Dr. Frary is a member of the American Institute of Mining and Metallurgical Engineers, The Institute of Metals, American Chemical Society, The Electrochemical Society, American Institute of Chemical Engineers, and The Chemists' Club. Of these he is a Past-President of The Electrochemical Society as well as a Past-President of the American Institute of Chemical Engineers.

Ohio State Welding Engineering Conference. The welding engineering department at Ohio State University has announced completion of the program for the 11th meeting of the Ohio State Welding Engineering Conference. Some 300 engineers, designers, and production supervisors from Ohio and neighboring states are expected to attend the campus meeting Friday and Saturday, April 14 and 15. This year's conference theme is "Economy in Design and Production." The first day of the program will be devoted to papers on design and welding, with economy in design the keynote, and the second day will be centered on production methods. Reservations for the conference can be made by writing the Department of Welding Engineering, Ohio State University, Columbus 10, Ohio.

RCA's Improved Multiplier Phototube. Important advances in nuclear research, astronomy, photoelectric spectrometry, and other fields involving work with light at extremely low levels are foreseen with the announcement of a greatly improved *1P21* multiplier phototube by the Radio Corporation of America's tube department. The "equivalent noise input" of the improved *1P21* has been reduced to 5×10^{-13} lumen at room temperature. This value represents a six-fold reduction in operational noise and permits a corresponding reduction in the lower limit of measurable light intensities. This extension in range of the improved *1P21* makes it an even more valuable aid for astronomers studying light from distant stars, for nuclear scientists studying atomic radiation, and for other laboratory research work requiring measurement of light of extremely low intensity.

New NBS Lab at Boulder. Approval has been given for the development of a site at Boulder, Colo., for additional National Bureau of Standards laboratory facilities. The site, to be used initially by the Bureau's Central Radio Propagation Laboratory, consists of about 210 acres, directly south of the city and close to the campus of the University of Colorado, and is to be dedicated to the Federal Government by the Boulder Chamber of Commerce. The National Bureau of Standards expects to erect laboratory facilities at Boulder for research in radio propagation at a cost of about $4,500,000 as authorized by Public Law 366 of the 81st Congress. It is expected that actual construction work on the radio laboratory will be started at Boulder during the summer of 1951. When the laboratory is completed a research staff of about 300 people will be employed there. Most of them will be transferred from the present staff in Washington.

Macaulay Directs G-E Work for AEC. Rear Admiral Walter S. Macaulay, United States Navy (Retired) has been appointed Assistant Executive Engineer in the Knolls Atomic Power Laboratory of the General Electric Company. The atomic laboratory, located near Schenectady, is being operated for the Atomic Energy Commission, as part of the company's Research Laboratory. Admiral Macaulay will be responsible for general administration in the atomic laboratory. At the same time, Lawrence L. Ferguson, who is also Assistant Executive Engineer, was named to direct the West Milton Area Project, where an experimental atomic power plant is under construction by the Atomic Energy Commission as part of the laboratory facilities. Mr. Ferguson is responsible for co-ordinating all phases of design and construction for this project, which is located at West Milton, N. Y., about 18 miles from Schenectady.

New Hydroelectric Works in Portugal

The new hydroelectric works at Castelo Do Bode, Portugal, are part of the hydroelectric development of the last 87 miles of the Zezere River before it flows into the Tagus, representing a total fall of 402 feet. The necessity for creating large reservoirs to regulate the variable flow and for utilizing the fall to the greatest advantage led to the establishment of four sections of which the Castelo Do Bode works are the largest. This section will have an installed capacity of 186,000 horsepower and an annual output of 700 million kilowatt-hours. It is expected to be completed by the end of 1950

New Interdepartmental Standards Council. Co-ordination of matters involving national and international standardization in which Federal Agencies are interested, is now being accomplished through a newly established Interdepartmental Standards Council. The new Council is composed of representatives from 15 Federal agencies and is headed by S. P. Kaidanovsky, of the Federal Supply Service of the General Services Administration. One purpose in establishing the Council, which meets monthly, is to provide machinery for the development of policy on national and international standardization matters of commercial significance as they concern the United States Government. Also, the Council will be of advantage to recognized groups and technical organizations within industry concerned with standardization matters by providing a medium through which they may obtain, when desired, the co-ordinated viewpoint of various Government agencies. In this connection, the Council will endeavor to encourage the maximum utilization and dissemination of information pertaining to standardization.

Michigan's Electric Power Supply Stepped Up. Michigan's electric power supply has been stepped up 100,000 kw with the starting of a giant new turbogenerator at the Trenton, Mich., Channel plant of the Detroit Edison Company. The amount of electricity produced by the new machine and its twin could satisfy the full demand of Ann Arbor, Ypsilanti, Pontiac, and Port Huron, Mich., combined. The 1,800,000-pound unit was put together by a General Electric Company crew in 26 days—the fastest time ever clocked in setting up a turbine of this kind and size.

H. W. Eales Retires. Herbert W. Eales, a former member and Past Vice-President of the AIEE, has retired from his position as Consulting Electrical Engineer for the Pioneer Service and Engineering Company of Chicago, Ill. Mr. Eales has been associated with the company for 23 years and is a graduate of Yale University. He is a member of Phi Beta Kappa, Sigma Xi, the Association of Edison Illuminating Companies, and the Edison Electric Institute.

Fischer and Porter Offers Instrument Course. April 10 to 14, inclusive, is the period of the second quarterly instrumentation course for 1950 conducted by the Fischer and Porter Company at its Hatboro, Pa., plant. Manufacture, calibration, installation, operation, and maintenance of the company's line of process control instruments will be covered in the course. Additional information can be obtained by writing to the Fischer and Porter Company, East County Line Road, Hatboro, Pa.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

The AIEE Emblem

To the Editor:

I was interested to observe that in presenting an answer to his electrical essay of December 1949 (*EE, Dec '49, p 1081*), A. A. Kroneberg in the January issue (*EE, Jan '50, p 51*) has described the 4-cusped hypocycloid as being "an outline of the AIEE emblem." Admittedly, the figure does resemble the Institute's emblem, but the true outline of the latter does not come within the scope of such a curve. I understand the form of the emblem to be that of Benjamin Franklin's kite, which was a square handkerchief stretched on a cross of two equal and mutually perpendicular rods. If this be true, the contour of the figure would be in the nature of four somewhat distorted catenaries, rather than a hypocycloid.

PERRY A. BORDEN (F '44)
(The Bristol Company, Waterbury, Conn.)

Editor's Note: As a matter of general interest, especially for the younger members, the following is a short history of the AIEE emblem and the significance of its design.

The original badge, used from August 1893 to April 1897, was of white enamel, the lettering and front portions of 18-karat gold, and the backing of 14-karat gold. The design was in the form of Franklin's kite, which demonstrated the identity between lightning and electricity and was a recognition of America's first "electrician" and philosopher, Benjamin Franklin. The arms or border of the kite formed a diagrammatic representation of the Wheatstone bridge. In the center was a tiny galvanometer, representing magnetism and induction. The galvanometer contained a blued steel needle, over which was a small disk of amber. The amber represents the first conception of electricity, dating back to 600 B.C. when Thales, the Greek philosopher, recorded the fact that amber, when rubbed, attracted light particles to it; and the Greeks worshipped it, believing that the gods had endowed it with life and that it possessed a soul. Amber also represents the derivation of the word electricity, coined in the year 1600 from the Greek word for amber, elektron, by Dr. Gilbert, court physician to Queen Elizabeth.

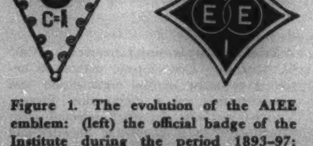


Figure 1. The evolution of the AIEE emblem: (left) the official badge of the Institute during the period 1893–97; (right) the fundamental form of badge adopted in 1897 and used, with only minor changes in proportion, continuously since then

Above the galvanometer were the letters A.I.E.E., the initials of the Institute; below the galvanometer was $C=\frac{E}{R}$, representing Ohm's law.

This badge apparently was not considered satisfactory, and on May 18, 1897, the design which, except for minor changes in proportion, is still in use today, was adopted. This design was chosen as a symbol of the broadest principle that could be found underlying the electrical engineering profession. Electricity always surrounds magnetism and magnetism always surrounds electricity and each forms a closed circuit. The relation between them, therefore, is always that of two closed links which pass through each other.

The present badge is of gold with different colors of enamel to indicate the grade of membership.

Harbor Radar

To the Editor:

A "Current Interest" item describing the installation of harbor radar at Baltimore, Md., which appeared in the February issue (*EE, Feb '50, p 180*) states that: "The only other ports in the world equipped with radar are Long Beach, Calif., and Liverpool, England." The source for this information evidently is not aware of the harbor radar installations in Canada.

The approaches to Halifax (Nova Scotia, Canada) harbor have been covered by radar for the past three years. The National Research Council installed and operates a system in the Camperdown signal tower outside Halifax. From this site, accurate information may be passed to vessels at a maximum range of 50,000 yards. Before information is passed to a vessel, she must first be positively identified by correlating her radar echo bearing and the radio bearing of the transmitter board. Advice is also passed to the pilot vessel on station, so that he may proceed and contact the approaching vessel. The vessels are easily directed to the pilot station.

Another National Research Council harbor radar installation has been in operation almost two years, from the center span of the Lions Gate Bridge across the entrance to Vancouver (British Columbia) harbor. From this location, the Radar Signals Officer commands an excellent radar view of the harbor on one side of the bridge and the approaches on the other side. Two synchronized radar antennas on either side of the center span provide uninterrupted coverage in both areas.

The bridge is equipped with radiotelephone on 1,630 kc and vessels are advised of their position and also of the traffic conditions in the channel. The Harbor Signals Officer controls traffic in the narrow entrance.

While the radar service in these two harbors has not yet been proclaimed officially, it has been used extensively by shipping since the dates of installation.

H. ROSS SMYTH

(Head, Radar Development Section, National Research Council ,Ottawa, Ontario, Canada)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

SATURATING CORE DEVICES, OPERATING PRINCIPLES AND APPLICATIONS. By L. R. Crow. Scientific Book Publishing Company, 530 South 4th Street, Vincennes, Ind., 1949. 373 pages, illustrations, diagrams, charts, tables, $8\frac{3}{4}$ by $5\frac{1}{2}$ inches, cloth, $4.20. Of interest to electrical engineering students as well as design and practicing engineers, this book is a collection of simplified descriptions of saturable core devices and applications. It is not intended as a source of specific design and performance data. It is rather a means to acquaint students with electric phenomena not to be found collected elsewhere. Descriptive and graphical methods are used.

ELECTRIC POWER INDUSTRY, PAST, PRESENT, AND FUTURE. By the Editorial Staff of *Electrical World;* McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 178 pages, illustrations, diagrams, charts, maps, tables, $11\frac{1}{4}$ by $8\frac{1}{2}$ inches, cloth, $3.50. Written by outstanding authorities in all the electrical fields, this book is a record of the evolution of energy generation, distribution, and utilization. It reports the progress of American electric-power systems, both private and public, and covers the philosophy and social and economic forces underlying this growth.

ELECTRICAL ESTIMATING. By R. Ashley. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 312 pages, illustrations, diagrams, charts, tables, 10 by $7\frac{1}{2}$ inches, cloth, $6.50. For the engineer and contractor who must solve complex problems of estimating, appraisal, cost accounting, job scheduling, or supervision in the electrical construction field. It sets forth the essential methods and practices of professional electrical estimating and provides in sample estimates and guides a basis for training new estimators.

Library Services

ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th Street, New York 18, N. Y.

FACSIMILE. By L. Hills and T. J. Sullivan. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 319 pages, illustrations, diagrams, maps, $9^1/_4$ by 6 inches, linen, \$3.50. This book is a nontechnical explanation of what facsimile is and of its growth and potential uses. Both "colorfax," transmitting of colored pictures, and "ultrafax," sending a million words a minute, are described. Frequency-modulation broadcasting, microwave relay, and other adjuncts of facsimile are covered. It also describes facsimile's use as a military weapon; for sending telegrams, air-line, police, school, railroad, and industrial information; and as a recording instrument.

FOURIER METHODS. By P. Franklin. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 289 pages, diagrams, tables, $8^1/_4$ by $5^1/_2$ inches, cloth, \$4. This text for engineering students covers harmonic analysis, complex exponentials, Fourier integrals, Fourier transforms, and Laplace transforms. A working knowledge of elementary calculus is assumed, but topics of advanced calculus are developed where needed. Applications to physical problems involving ordinary and partial differential equations are included. There are many sets of practice problems with answers.

INDUSTRIAL HIGH-FREQUENCY ELECTRIC POWER. By E. May. Chapman and Hall, Ltd., London, W. C. 2, England, 1949. 355 pages, illustrations, diagrams, charts, tables, $8^3/_4$ by $5^1/_2$ inches, cloth, 32s. Based on lectures presented at Birmingham Central Technical College, this book serves as an introduction to high-frequency technology. The first chapter is devoted to a summary of elementary a-c circuit theory. Industrial high-frequency generators at present in use—spark and arc generators, motor generators, and valve-generators—are then discussed in detail. Induction and dielectric heating are considered, and the final chapter describes typical applications and operating problems.

METAL CUTTING TOOL HANDBOOK. Metal Cutting Tool Institute, 405 Lexington Avenue, New York, N. Y., 1949. 647 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$6.50. This handbook presents complete and up-to-date information on various types of metal cutting tools, their operation and maintenance. There are sections on twist drills, reamers, counterbores, taps, dies, milling cutters, hobs, gear shapes, cutters, and broaches. Each section contains pertinent data on speeds, feeds, operating conditions, sharpening, and maintenance instructions. There are also tables of commercial sizes of each type. An engineering data section is also included.

MODERN ELECTRIC CLOCKS. By S. F. Philpott. Fourth edition. Pitman Publishing Corporation, New York, N. Y., and London, England, 1949. 228 pages, illustrations, diagrams, charts, tables, $7^1/_2$ by 5 inches, linen, \$4.50. A complete outline of the principles, construction, and installation of typical clock systems, including the points to be considered in the selection of a suitable clock for all purposes. The book provides detailed information for the experienced clockmaker as well as a thorough groundwork for apprentices and electricians.

NUMERICAL ANALYSIS OF HEAT FLOW. By G. M. Dusinberre. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 227 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$4.50. This book presents in a learnable, usable form, modern numerical methods for the calculation of heat flow in solids. These finite-difference methods are free from many of the limitations of conventional differential analysis. Based on material heretofore scattered in the literature, a variety of techniques is included for the solution of problems, whether in the field of steady state or transients.

PATENT TACTICS AND LAW. By R. S. Hoar. Third edition. Ronald Press Company, New York, N. Y., 1950. 352 pages, $9^1/_4$ by 6 inches, cloth, \$7. Of interest to the engineer, independent inventor, and business executive, this book constitutes a translation into plain English of essential patent law. Particularly noteworthy in this third edition are the changes in the handling of appeals within the Patent Office and new practices based on recent changes in the "Rules by Practice" and "Manual of Patent Examining Procedure" published by the Patent Office. A considerable number of case citations have been added, as footnotes, as well as a glossary of terms relating to patent law.

PREVENTION OF IRON AND STEEL CORROSION, PROCESSES AND PUBLISHED SPECIFICATIONS. Compiled by C. Dinsdale. Louis Cassier Company, Ltd., distributed by Iliffe and Sons, Ltd., London, Birmingham, Coventry, and Manchester, England, and Glasgow, Scotland, 1948. 88 pages, tables, $8^3/_4$ by $5^1/_2$ inches, cloth, 5s. The object of this book is to provide a complete index of methods, processes, and standard specifications relating to the prevention of corrosion of iron and steel. The material is divided into three parts dealing respectively with prevention methods, cleaning metal parts, and codes of practice. An appendix deals with paint and paint component specifications. Specifications relating to alloyed iron and steel are not included.

PRINCIPLES OF A NEW ENERGY MECHANICS. By J. Mandelker. Philosophical Library, 15 East 40th Street, New York, N. Y., 1949. 73 pages, diagrams, charts, $9^1/_2$ by 6 inches, fabrikoid, \$3.75. This book explains this new branch of physical science which represents the next step of an evolution, leading from Newton's classical mechanics through Einstein's relativity theory as an intermediate stage. Part 1 is devoted to a development and statement of principles, and Part 2 shows how the principles explain physical phenomena.

(The) PROTECTION OF TRANSMISSION SYSTEMS AGAINST LIGHTNING. By W. W. Lewis. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1950. 418 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$8. This book assembles the most important information on lightning and applies it to the design and protection of transmission lines and stations. It contains practical rules which plant owners, designers, constructors, engineers, and operators can use in their work. Rules are given for the proper co-ordination of line insulation and spacing of conductors, for the best arrangement of overhead ground wires, and for grounding lines and stations. Various alternative methods of protecting low- and high-voltage transmission lines, stations, and rotating machines are also discussed.

PUMP QUESTIONS AND ANSWERS. By R. Carter, I. J. Karassik, and E. F. Wright. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; and London, England, 1949. 346 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$5. This book covers the construction, application, operation, installation, and maintenance of pumps. In five major sections, centrifugal, vertical turbine, regenerative, rotary, and reciprocating pumps are dealt with separately.

TRANSFORMER PRINCIPLES AND PRACTICE. By J. B. Gibbs. Second edition. McGraw-Hill Book Company, New York, N. Y., 1950. 236 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$3.50. In a simple nonmathematical style, this book deals with all aspects of the construction and use of transformers, including underlying principles, applications, connection, testing, care, and economics. Following introductory material, many particular types of transformers are described. This revised second edition includes a new chapter on current-limiting reactors as well as new illustrations showing up-to-date construction.

VACUUM EQUIPMENT AND TECHNIQUES. Edited by A. Guthrie and R. K. Wakerling. (National Nuclear Series, Division I—Volume I.) McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 264 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$2.50. Concerned with the study and development of high-vacuum practice, this book is a compilation of observations made by the personnel of the University of California Radiation Laboratory in the course of developing high-vacuum equipment for use in electromagnetic separation plants. One topic of particular interest is the use of the vacuum analyzer and helium leak detector which were developed for use in the project. Throughout the book liberal reference is made to the available published literature.

SCIENTIFIC AND TECHNICAL ABBREVIATIONS, SIGNS AND SYMBOLS. By O. T. Zimmerman and I. Lavine. Second edition. Industrial Research Service, Dover, N. H., 1949. 541 pages, illustrations, $8^1/_2$ by $5^1/_2$ inches, cloth, \$8 (\$9, foreign countries). Following a large general list of abbreviations, alphabetized by the terms abbreviated, the specialized signs, symbols, and abbreviations are grouped into several fields: mathematics, chemistry, physics, thermodynamics, aeronautics, radio, electronics, topography, astronomy, biology, medicine, commerce, the various branches of engineering and so forth. This second edition has been revised to conform with recently adopted standards and codes, and new material has been added particularly in the form of graphical symbols.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Color TV—Now or Later? Gives a technical description of the various color television systems now under development, outlining the advantages and limitations of each. Priced at one dollar, this report is available from The Television Research Institute, 207 East 43d Street, New York 17, N. Y.

Light for Machining Small Metal Parts. One of the Illuminating Engineering Society's Lighting Study Projects for Industry, this 16-page report recommends lighting for operations from general and supplementary lighting through lighting for specific tasks, with special attention in the latter section to measuring instruments and rules and graduated feed indicating scales. Copies are available at 50 cents per copy from the Publications Office, Illuminating Engineering Society, 51 Madison Avenue, New York 10, N. Y.

Bibliography on Gas Turbines, Jet Propulsion and Rocket Power, by Ernest F. Fiock, National Bureau of Standards Circular 482. A complete bibliography of books and periodicals published since 1940 covering jet engines, gas turbines, rockets, compressors, turbines, combustion chambers, aerodynamics, metallurgy, machining and welding, and ceramic materials in gas turbines. This 49-page pamphlet is available for 20 cents from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Handling Radioactive Wastes in the Atomic Energy Program. This nontechnical report describes radioactivity and its biological effects, the types and sources of radioactive wastes in the atomic energy program, and the methods used for safe handling of wastes and protecting workers and the public from radioactive contamination. Copies of the report are available at 15 cents each from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Unified Screw Thread Standards. Proceedings of the joint session of representatives of Canada, Great Britain, and the United States on the unification of screw threads, November, 1948 and the standards of unified form of thread, thread series, classification and tolerances, and tables. Available at 20 cents from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

A Brief for Corporation Libraries, by Alma C. Mitchill. This 64-page manual is designed to assist in the organization and administration of a corporation library. Various methods described selected from practices in effect in existing libraries and found to be practicable. A bibliography serves as a guide to more extensive study. Available at \$1.75 per copy from Special Libraries Association, 31 East Tenth Street, New York 3, N. Y.

This "eye" scouts new telephone frontiers

Throughout history, scouting parties have gone out ahead of man, ahead of settlements, ahead of civilization itself. Today, Bell System scouts are engaged in a new kind of exploration — charting a path for microwaves — using equipment specially designed by Bell Telephone Laboratories.

The portable tower shown is constructed of light sections of aluminum and in a few hours may be built up to 200 feet. Gliding on rollers, the "dish," with its microwave transmitter or receiver, is quickly positioned for line-of-sight transmission, then oriented through electric motors controlled from the ground.

Test signals show how terrain and local climate can interfere with microwave transmission. Step by step, Bell's explorers avoid the obstacles and find the best course for radio relay systems which will carry television pictures or hundreds of simultaneous telephone conversations.

A radio relay link similar to the one between New York and Boston will be opened this year between New York and Chicago. Later it will be extended, perhaps into a nation-wide network — another example of the way Bell Telephone Laboratories scientists help make the world's best telephone system still better each year, and at lowest cost.

BELL TELEPHONE LABORATORIES

EXPLORING AND INVENTING, DEVISING AND PERFECTING, FOR CONTINUED IMPROVEMENTS AND ECONOMIES IN TELEPHONE SERVICE

YOU CAN BE **SURE**.. IF IT'S
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THIS NEW PORTABLE IS ONLY ONE EXAMPLE OF HOW YOU CAN MEET ALL ELECTRICAL MEASURING REQUIREMENTS . . . PORTABLE . . . SWITCHBOARD . . . PANEL.

Here's Why...

- ★ **The most complete line** in the industry! Supply your instrument needs from one source.
- ★ **Shipments in 10 days!** We can meet practically every electrical measuring requirement 10 days from receipt of order at the factory.
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The First LOW-COST PORTABLE of its kind!

★ **Magnetically shielded...**

may be used anywhere—guarded against errors due to proximity of other instruments, high current busses, magnetic fields or magnetic materials.

★ **Convenient pocket-size...**

small and compact—without sacrifice of performance—completely insulated for safe use.

★ **Complete variety of ratings...**

in a-c, d-c and rectifier types for the full range of current and voltage measurements.

Westinghouse has this great, new, portable instrument line ready for you now ... the first instruments in the low-priced field that are specifically designed and manufactured to provide *all* of these features. Phone, write or wire your nearest Westinghouse representative. He will have an experienced instrument specialist help you plan your needs, whether they be portable, panel or switchboard instruments. Write for C.S. 43-100. Westinghouse Electric Corporation, 95 Orange Street, Newark, New Jersey.

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S-14-A

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12" x 5¾" x 7"

A portable oscilloscope engineered to the exacting requirements of the electronic designer . . . a precision instrument that sacrifices nothing in performance characteristics or dependability because of its portable size or budget price . . . A giant in performance, a midget in size, the S-14-A POCKETSCOPE invites critical comparisons!

Identical Vertical and Horizontal channels with 10 mv/in sensitivity, response from 0 to 200KC within —2DB . . . Non frequency discriminating attenuators and gain controls . . . Internal calibration of trace amplitude . . . Linear time base oscillators with ± sync for either repetitive or trigger sweeps, from ½ cycle to 50KC . . . Trace expansion . . . Filter screen . . . Mu metal shield . . . and a host of other features.

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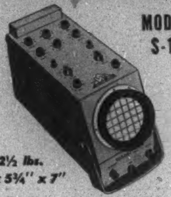
S-15-A TWIN-TUBE POCKETSCOPE
Also, RAKSCOPES, Linear Amplifiers, RAYONIC tubes and other equipment.



INDUSTRIAL NOTES ....

Sylvania News; Appointments. The California Sales Division of Sylvania Electric Products, Inc., has been reorganized into two separate divisions in order to coordinate sales and warehouse activities in each area—the Central Pacific Division, with headquarters in San Francisco, and the South Pacific Division, with headquarters in Los Angeles. The Northwestern Division, headquartered in Seattle, will remain in operation to service that section of the country. Robert C. Harper was appointed Division Sales Manager of Lighting Products for the Central Pacific Division; and Charles I. Brady has been named to the same position in the South Pacific Division.

Sylvania has also announced the following appointments: George C. Connor as General Sales Manager for the Photoflash Division, and Alfred C. Viebranz as General Sales Manager of the Electronics Division.

Grove Chief Engineer of Cornell-Dubilier's Ceramic Division. R. L. Grove has been named Chief Engineer of the Cornell-Dubilier Electric Company's Ceramic Division in New Bedford, Mass. Mr. Grove's new position includes setting up the manufacture of a line of ceramic capacitors, as well as the establishment of a ceramic research and control laboratory.

Westinghouse Opens New Plant; Other News. The Westinghouse Electric Company has announced the start of manufacturing operations at the company's new plant near Irwin, Pa. The plant, employing about 25 women, will make an entirely new insulating product that has never before been manufactured by Westinghouse. It is hoped that eventual employment at the Irwin plant may reach 250 to 300 people. The new plant was acquired by Westinghouse in March 1948, as part of a $132,000,000 long-range, company-wide expansion and improvement program.

The company has also announced the formation of three new sales divisions of the Middle Atlantic District of the Westinghouse Lamp Division, with corresponding appointments: Harry A. Croasdale has been appointed Manager of the Penn-Jersey Lamp Sales Division, which includes eastern Pennsylvania, south Jersey, Delaware, and the eastern shore of Maryland; Edward S. Barrington has been named Manager of the Chesapeake Lamp Sales Division (with headquarters in Baltimore, Md.) which includes the remainder of Maryland, northern Virginia, eastern West Virginia, and the District of Columbia. The Virginia Lamp Sales Division, with headquarters in Richmond, Va., will be headed by John C. Downing. This area includes lower-belt Virginia, northeast North Carolina, southern West Virginia, eastern Kentucky and eastern Tennessee.

The company has also announced the following appointments: Burt S. Burke, Manager of the Lighting Division of the corporation at Cleveland, Ohio; C. Swan Wever, Manager of the Eastern District of the Westinghouse Electric Corporation, with headquarters in New York; S. F. Davies, Jr., Manager of the commercial, industrial, and floodlighting section of the Lighting Division, at Cleveland, Ohio; and J. P. Barbour, Manager of the Small Motor Division's Aircraft Department, at Lima, Ohio.

American Steel and Wire Company Appointment. Umbert F. Corsini has been named General Superintendent of the American Steel and Wire Company's South Works in Worcester, Mass. The new superintendent, who occupies the post vacated by Van H. Leichliter, was appointed Assistant Vice-President of the company recently.

Alcoa to Roll Magnesium Sheet at New Kensington. A new division for the rolling of magnesium sheet will be established by the Aluminum Company of America at its New Kensington, Pa., works in the near future. Alcoa has established this new division because of greatly increased demand for magnesium sheet in airplane construction and other phases of the national security program. Magnesium rolling operations were conducted at the company's New Kensington Works for a number of years in times past, but were discontinued in 1947 because of the sharp drop in demand after World War II.

General Electric Retirement; Appointments. Harold D. Blake, Technical Director of the Lamp Development Laboratory at Nela Park, has retired after over 40 years of continuous service to the company. The company has also announced the appointment of James D. Lowe as Wire and Cable Specialist for the Construction Materials Department, at Bridgeport, Conn. New assignments for key personnel in the General Electric Company's Apparatus Department were also reported recently: T. D. Foy was named Administrative Assistant; and F. J. Boucher, D. S. Lisberger, and H. B. Miller were named staff assistants to F. T. Lewis, Manager of Manufacturing.

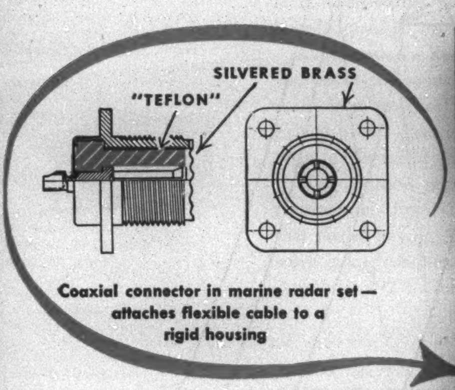
Mead Manager of Lear California Division. C. E. Mead has been named Manager of the LearCal Division of Lear, Inc. The LearCal Division, at 11916 West Pico Boulevard, Los Angeles 64, Calif., is a research and development center as well as local headquarters for its sales and service.

Honeywell Completes St. Louis Branch Building; Appointment. The St. Louis Branch of the Minneapolis-Honeywell Regulator Company and its Brown Instruments Division has moved into its new office building at 4354 Olive Street. The new

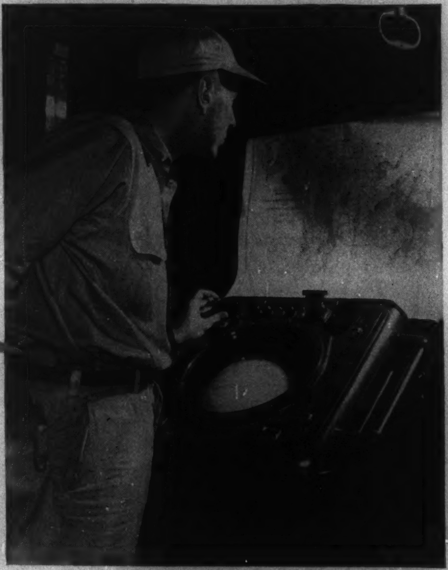
(Continued on page 28A)

DU PONT "TEFLON"*

gives maximum efficiency, durability in co-ax connectors for Sperry radar set



Coaxial connector in marine radar set—attaches flexible cable to a rigid housing



Connectors made by Industrial Products Division, Danbury-Knudsen, Inc., Danbury, Conn., for Sperry Gyroscope Co., Great Neck, L. I., N. Y.

Tough new plastic has low dielectric constant, low loss factor, excellent heat-resistance

When a material requirement calls for *low* dielectric constant, *low* loss factor, high heat-resistance, toughness, resiliency—there is *one* material that has all these properties, Du Pont "Teflon" tetrafluoroethylene resin. That's why "Teflon" is superior to all other materials for use in high-frequency connectors. That's why Sperry uses "Teflon" for the insulation in the coaxial connectors for this marine radar set. "Teflon" provides unequaled transmission efficiency plus outstanding durability.

First, "Teflon" has a low dielectric constant (2.0), constant over the entire range of frequencies measured to date. This minimizes step discontinuities that produce reflections of power. In addition, it has a low loss factor (0.0005)—so that little power is lost at the connector, and the insulation does not heat up in service.

Along with these outstanding electrical properties, "Teflon" has high heat resistance (serves up to 500°F.), eliminates danger of melting the insulation when soldering connections during assembly. It's tough, too, even at temperatures as low as -90°F., won't break or crack if connectors are dropped or banged, has just enough resiliency to give and conform when stressed during installation.

"Teflon" is supplied by Du Pont in standard shapes (rods, tubes, sheets and tape) and molding powders. Or we will recommend molders or fabricators who can supply finished parts of "Teflon." Write today for more information. Our technical staff will be glad to help you. E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department, Plastics Sales Offices: 350 Fifth Ave., New York 1, N. Y.; 7 S. Dearborn St., Chicago 3, Ill.; 845 E. 60th St., Los Angeles, California.

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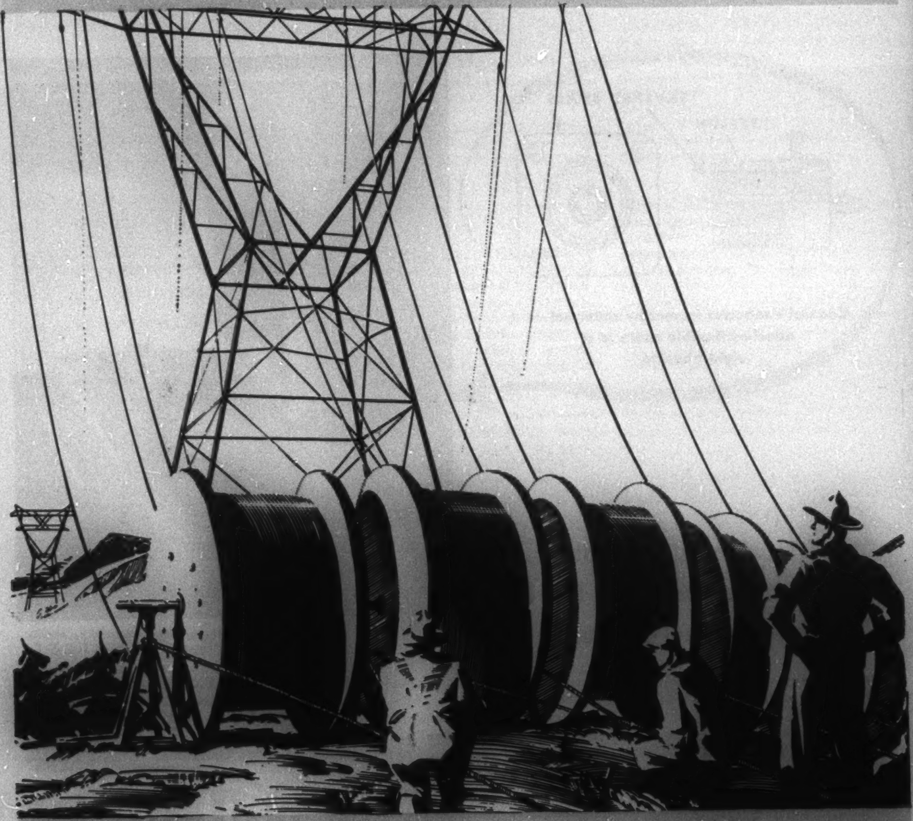


ALCOA FIRST IN ALUMINUM

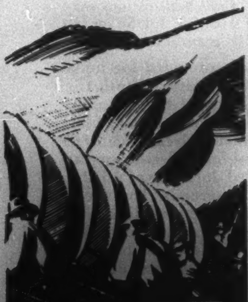
but what do they mean to you?

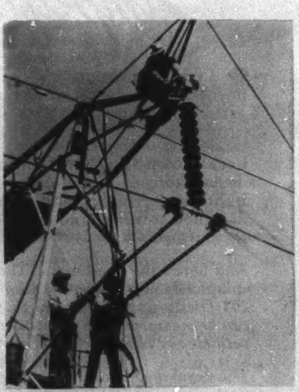
They mean that you get more than just cable when you buy from Alcoa—that you're tapping the world's greatest store of knowledge of ACSR problems. Think of this:

Alcoa made the first ACSR. Did the research that made possible mile-long spans. Developed the installation methods that made them practical. And today, Alcoa, with the momentum gained in this experience, is pushing forward to more knowledge of conductor problems.

That constant search promises better service from your transmission lines, lower maintenance. It's your assurance that you're buying ACSR from those who can best help you solve your conductor problems. ALUMINUM COMPANY OF AMERICA, 1927C Gulf Building, Pittsburgh 19, Pennsylvania.

TYPICAL of Alcoa research is armor rodding—now commonplace—developed 25 years ago to prolong the life of overhead conductors. Alcoa Armor Rods reinforce cable in the vital few inches of greatest stress, dampen vibration, prevent fatigue rupture of strands. They are also used to repair conductors which have previously suffered damage from vibration, burning or abrasion. Write for your free copy of the new Alcoa booklet on this subject to Aluminum Company of America, 1931D Gulf Bldg., Pittsburgh 19, Penna.





Installing Alcoa Armor Rods with hot-line tools on a 220,000-volt line without interrupting service.

® ALCOA ALUMINUM

FOREMOST IN A·C·S·R

Simplified STUDY OF LIGHTNING

➡ Lightning—nature's violent electrical impulse—places great strain on even the most perfectly devised high-voltage insulation.

Therefore, testing the effects of insulation breakdown is of vital importance in the manufacture of high-voltage transformers, lightning arresters, and other equipment designed to withstand transient signals of excessive amplitude.

And here's the good news: The design of the completely new and specialized Du Mont Type 293 Oscillograph indicates that these effects *can be measured with a hot-cathode, sealed-off cathode-ray tube.*

The development of the Du Mont Type 5RP-A Cathode-ray Tube has made possible the visual and photographic observation of writing rates involved in surge testing. For calibration of a typical impulse test-wave, a d-c voltmeter provides continuous, direct-reading accuracy within 1% of full scale. Time calibrations may be made at intervals of 0.05, 0.1, 1.0, 50 or 250 microseconds, with 0.2% accuracy.

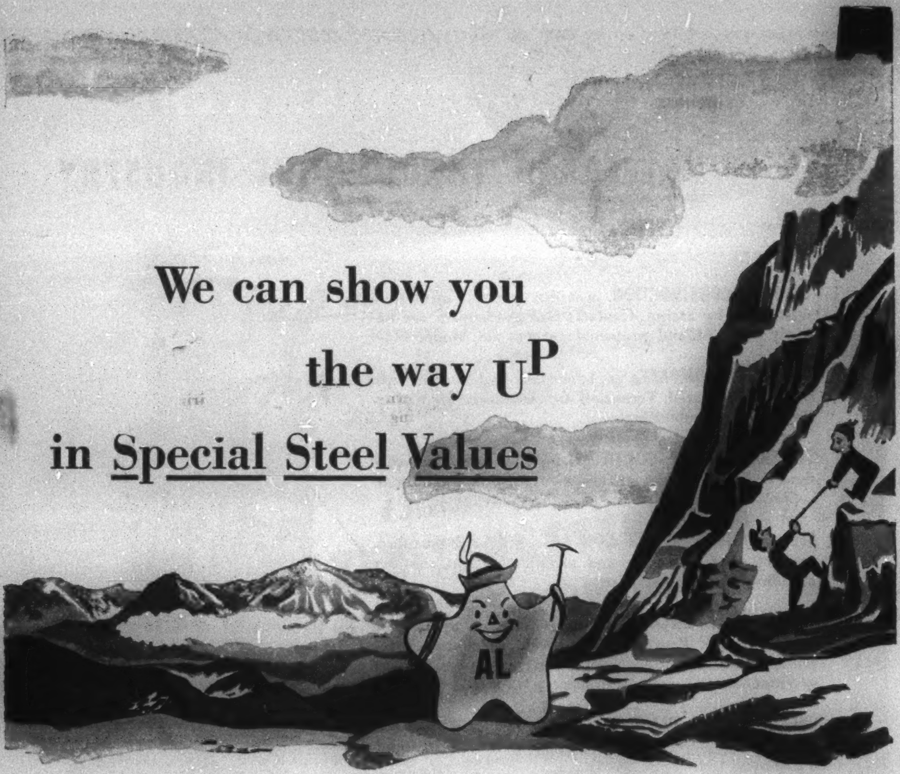
Adequate attenuators are provided for input signals as high as 2500 volts on both the horizontal and vertical axes of the Type 293 Oscillograph, where one quantity is to be plotted as a function of another. Driven, undelayed sweeps are also provided for deflection on the horizontal axis with fixed durations of 0.5, 2.5, 10, 50, 250 or 1000 microseconds. The sweep voltage is logarithmic, assuring good definition of the early part of the steep wavefront. Permanent records of the test surge may be made with a detachable 35 mm camera, using an f/1.5 lens, provided with the Type 293 Oscillograph.

➡ **A complete description of this new and important advancement in the field of surge testing may be obtained by writing to the Instrument Division, Allen B. Du Mont Laboratories, Inc., Clifton, N. J.**

DUMONT *for Oscillography*

ALLEN B. DUMONT LABORATORIES, INC. · INSTRUMENT DIVISION, 1000 MAIN AVENUE, CLIFTON, NEW JERSEY

We can show you the way UP in Special Steel Values



The only real value in a material lies in what it will *do* for you. Will it improve the quality of your products—let you give more to the user at the price? Or, on the other hand, will it improve your cost position—help to keep open your vital area of profit?

When you begin to think about better materials, you're automatically in the field of special high-alloy steels—*and Allegheny Ludlum*. From the various AL families of stainless and heat-resisting steels, tool steels and sintered carbides, special high-temperature alloys and electrical materials, let us help you to select the metals that will yield the benefits you're looking for.

Just remember that the first cost of a special steel may be only a little, if any, more than the material it replaces—and it's usually many times cheaper in the long run. ● *Our Technical Staff is fully at your disposal.*

Complete technical and fabricating data—engineering help, too—yours for the asking.

ALLEGHENY LUDLUM STEEL CORPORATION

The Nation's Leading Producer of Stainless Steel in All Forms

W&D 2333

Pittsburgh, Pa. . . . Offices in Principal Cities

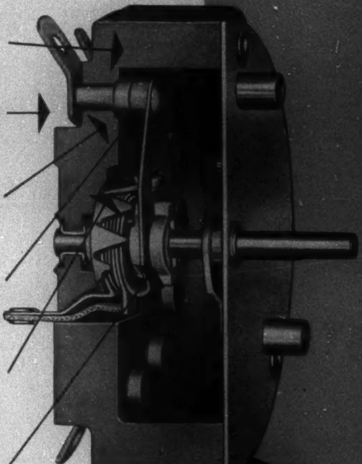
Allegheny Metal is stocked by all Jos. T. Ryerson & Son, Inc., Warehouses

High-Current, Rotary

OHMITE TAP SWITCHES

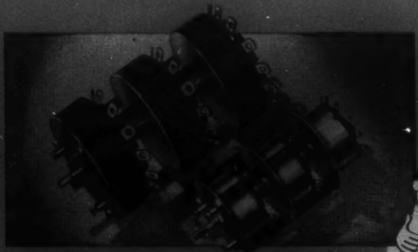
—PREFERRED THROUGHOUT INDUSTRY

1. **CERAMIC CONSTRUCTION** provides perfect insulation, unaffected by arcing. Contacts and mechanism are entirely enclosed and protected (except for Model 111).
2. **EXTREMELY COMPACT,** yet have many high-current taps, perfectly insulated. Terminals are convenient for wiring. Back-of-panel mounting.
3. **SILVER-TO-SILVER CONTACTS,** for high electrical conductivity. Have low surface resistance, and eliminate contact maintenance.
4. **SELF-CLEANING ROTOR CONTACT.** Slightly rounded, assuring perfect seating and producing slight rubbing motion with every operation.
5. **"SLOW-BREAK" MECHANISM,** incorporating a positive cam-and-roller. Provides "slow-break, quick-make" action, particularly suited to alternating current. Minimizes sparking, extends contact life.
6. **"DEAD" SWITCH SHAFT.** Completely insulated from the load by a high-strength driving hub which will withstand a 2000-volt test.



5 SIZES
10 to 100 Amp.
A-C

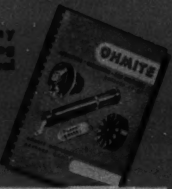
AVAILABLE IN TANDEM MOUNTINGS



Have many applications, including simultaneous control of separate circuits. Extended shafts, with universal coupling for single-knob control of two or three switches.

Write on Company Letterhead for Catalog and Engineering Manual No. 40.

OHMITE MFG. CO.
4902 Flournoy Street
Chicago 44, Ill.



OHMITE
Reg. U. S. Pat. Off.

RHEOSTATS • RESISTORS
TAP SWITCHES

25th Anniversary
1925-1950

ON circuit breakers . . .
Motor controllers . . .
Transformer protective equipment
. . . Aviation relays . . . Contactors
. . . and similar equipment

Chances are . . .

STACKPOLE SILVER-TUNGSTEN CONTACTS can save you money!

One of the most remarkable contact developments of recent years, Stackpole Silver-Tungsten Contacts have scored an outstanding performance record on a long list of difficult applications.

In particular, they are ideally suited for assuring low contact resistance under continued operations where heavy arcs are present or under closed conditions. Exceptionally high characteristics of strength, density and conductivity make this performance possible.

CONTACTS "TAILORED" to YOUR EQUIPMENT

Actually, there are only a few standard grades of Stackpole Silver-Tungsten Contact materials. The procedure in most cases is to adapt the percentages of materials in the contact mix to the contact operating requirements of a specific application. Preferably, this calls for laboratory testing of different contact compositions on the equipment under actual operating conditions—and this is a service Stackpole is glad to render for contact users. Send details of your equipment and its applications and we will gladly recommend either specific contacts or a laboratory test procedure that may result in a worthwhile saving. Stackpole contacts are sold only to makers of original equipment—not for replacement uses.

For a wealth of general contact information as well as specific data on Stackpole grades, write on company stationery for Stackpole Contact Catalog 12.

Grade	Composition % Silver	Cross Breaking Lbs. per Strength Sq. In.	Hardness Rockwell Superficial	Density	Electrical Conductivity Ag=100	Contact Resistance Estimated Ag=100
FW56	70	57,000	15T75	12.0	75	120
FW49	50	82,000	30T56	13.2	55	150
FW41	35	108,000	30T72	14.6	45	200
FW34	32	110,000	30T70	14.7	40	250

TYPICAL STACKPOLE SILVER-TUNGSTEN CONTACT MATERIALS

"Everything in Carbon but Diamonds"

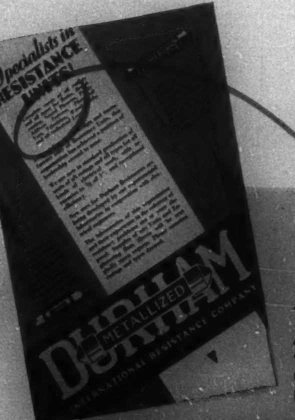
STACKPOLE CARBON CO., ST. MARYS, PA.

STACKPOLE

Age is for resistors *too!*

IRC
ELECTRONICS

20 years ago, IRC advertised resistors for *television!* And right now, while we produce for today's requirements, electronics 1970 is on our drawing boards. 25 years young this year, IRC combines a quarter-century of specialized engineering with free, fresh thinking on new resistance problems. Result of this concentration:—A unique variety of high-quality, lower-cost resistance products, plus *unbiased* recommendations.

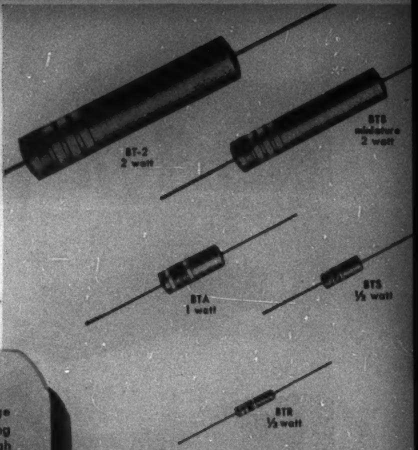

Specialists in RESISTANCE UNITS!

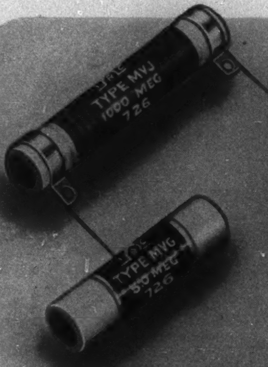
DURHAM
METALLIZED
INTERNATIONAL RESISTANCE COMPANY

TELEVISION IN 1930

Advertising resistors for television 20 years ago was not nearly so advanced as IRC's present planning for the future.

important





LESS THAN 3% change from original value due to aging has been proven for MV High Voltage Resistors. The resistance coating of Type MV's is stabilized at high temperature. Application of this filament coating in helical turns on a ceramic tube gives a conducting path of long effective length and permits the use of up to 100,000 volts for the MVR resistor. For high voltages where high resistance and power are required Type MV's are available in a wide range of values, sizes and terminals, all described in Bulletin G-1. Use the coupon to get your copy.

AGING IS NO PROBLEM

with Advanced BT Resistors. Filaments are pre-cured and stabilized, practically eliminating any possibility of resistance change through aging. Engineered to meet JAN-R-11 specifications for fixed composition resistors, IRC BT's have established their superiority in all important characteristics. Let us prove it to you . . . check the coupon for 12 page technical data Bulletin B-1. 21 characteristic charts compare IRC performance to rigid JAN specifications.

AFTER 10,000 CYCLES

of rotation IRC's new Q Control shows less than 10% change in resistance for values below 1 megohm, and not over 15% change for values of 1 megohm and above. Noise level after the same rigorous tests remains well within the industry standard for new controls. Investigate the many advantages of this modern size 15/16'' diameter control. Complete mechanization in manufacture assures you of absolute uniformity and a dependable source of supply. Coupon brings you full details on Bulletin A-4.

25 YEARS YOUNG
IRC
IN 1950

IRC

Wherever the Circuit Says -ᴧᴧᴧ-

Power Resistors • Voltmeter Multipliers • Insulated Composition Resistors • Low Wattage Wire Wounds • Controls • Rheostats • Voltage Dividers • Precisions • Deposited Carbon Precistors • High Frequency and High Voltage Resistors • Insulated Chokes

**INTERNATIONAL
RESISTANCE COMPANY**

401 N. Broad Street, Philadelphia 8, Pa.
In Canada: International Resistance Co., Ltd., Toronto, Licensee

**INTERNATIONAL RESISTANCE CO.
411 N. BROAD ST., PHILADELPHIA 8, PA.**

Please send me complete information on the items checke below:

☐ MV High Voltage Resistors (G-1) ☐ New Q Controls (A-4)
☐ Advanced BT Resistors (B-1) ☐ Name of Local IRC Distributo

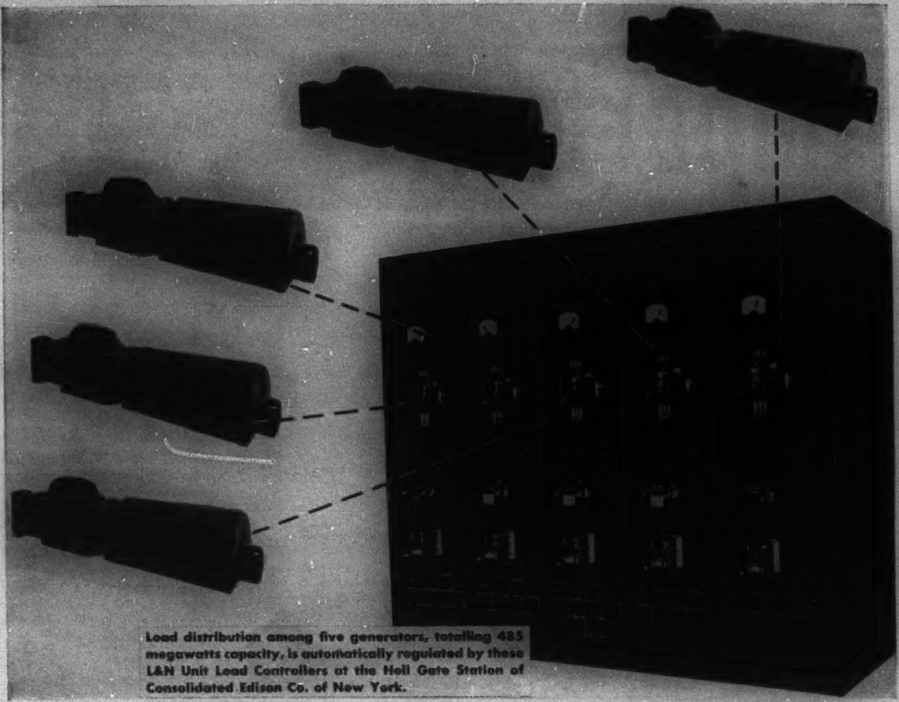
NAME..

TITLE..

COMPANY..

ADDRESS..

J. F. ARNDT & CO., ADV. AGENC



Load distribution among five generators, totalling 485 megawatts capacity, is automatically regulated by these L&N Unit Load Controllers at the Hell Gate Station of Consolidated Edison Co. of New York.

"Load Dispatcher" for each unit cuts generation costs

Changes in power demand necessarily mean changes or swings in the amount of power generated—and often affect the cost of producing power. One of the best ways to cut these costs is to spread the load swings among as many generators as possible. Then when load varies, each generator contributes only a relatively small share of the change, and thus can stay at steadier output, close to its own range of best efficiency. In other words, planned distribution reaches a firmer basis all the way down to the individual generators.

The complexity and tediousness of manual load distribution are eliminated in many plants by having this work done automatically through L&N Unit Load Control. Each L&N Controller acts, in effect, as a "load dispatcher" for its own generator. It watches the total load on the station, and when a change comes along, it tells its generator how much of the change to take. The percent of total load assigned to each generator can be varied readily at the operator's discretion, by means of suitable dials. Quickly and efficiently, he can adjust the whole station's generating picture to handle economically any load situation which may arise.

L&N Unit Load Control works with your existing load-frequency control equipment, and can be applied to practically any generating unit. For details, write to Leeds & Northrup Company, 4962 Stenton Avenue, Philadelphia 44, Pennsylvania.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl Ad ND44-56-461(2)

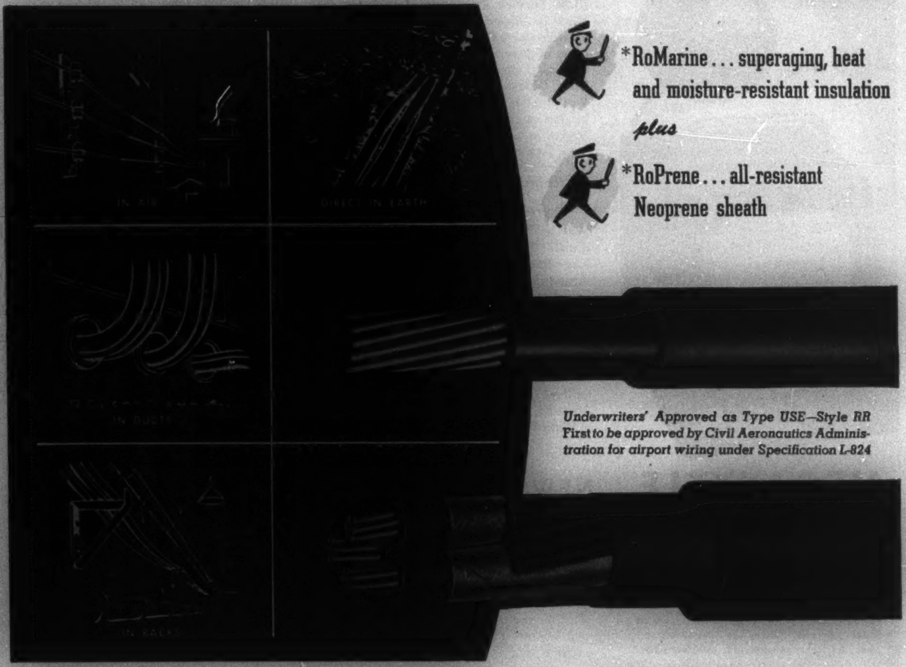
You get Double* Protection

with RoMarine - RoPrene

*RoMarine . . . superaging, heat and moisture-resistant insulation

plus

*RoPrene . . . all-resistant Neoprene sheath



Underwriters' Approved as Type USE—Style RR First to be approved by Civil Aeronautics Administration for airport wiring under Specification L-824

RoMarine-RoPrene enjoys its high popularity as a dependable power cable with good reason. It offers *double protection* against circuit failures. First, its RoMarine insulation is both heat and moisture resistant. Second, its RoPrene sheath is highly resistant to oils, acids, corrosive fumes and flame. It is unaffected by electrolysis, weather hazards or extreme temperature change.

Add to this, versatility of application and you can understand why more and more utilities and industrials are swinging to RoMarine-RoPrene, the all-purpose cable. Installed direct in earth, in conduit, in air, or in runs combining all three, RoMarine-RoPrene is ideal for secondary networks, underground entrances, street lighting, station control circuits, or general purpose wiring. It is cheaper than lead sheathed cable. It is lighter . . . easier to handle and splice . . . Write for Specification RR-1 for test data and construction details.

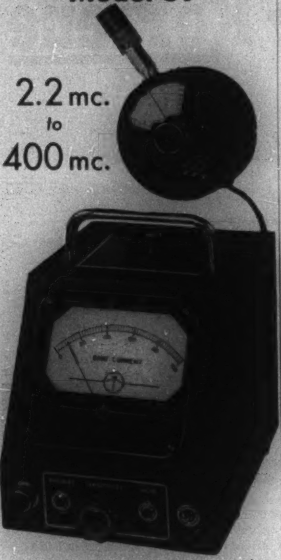
It Costs Less to Buy the Best . . . Buy Rome Cable

ROME CABLE CORP., Dept. EE-4, Rome, N. Y.
Please send me Specification RR-1 (Test Data).

Name ....
Company ....
Address ....
City .... *State* ....

ROME CABLE
Corporation
ROME - NEW YORK
From Bar to Finished Wire

MEASUREMENTS CORPORATION
Model 59



MEGACYCLE METER

Radio's newest, multi-purpose instrument consisting of a grid-dip oscillator connected to its power supply by a flexible cord.

Check these applications:

- For determining the resonant frequency of tuned circuits, antennas, transmission lines, by-pass condensers, chokes, coils.
- For measuring capacitance, inductance, Q, mutual inductance.
- For preliminary tracking and alignment of receivers.
- As an auxiliary signal generator; modulated or unmodulated.
- For antenna tuning and transmitter neutralizing, power off.
- For locating parasitic circuits and spurious resonances.
- As a low sensitivity receiver for signal tracing.

TELEVISION INTERFERENCE
The Model 59 will enable you to make efficient traps and filters for the elimination of most TV interference.
Write for Special Data Sheet, 59TVI

SPECIFICATIONS:
Power Unit: 5⅛" wide; 6⅛" high; 7½" deep. Oscillator Unit: 3¾" diameter; 2" deep.
FREQUENCY:
2.2 mc. to 400 mc.; seven plug-in coils.
MODULATION:
CW or 120 cycles; or external.
POWER SUPPLY:
110-120 volts, 50-60 cycles; 20 watts.

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

(Continued from page 16A)

building, which cost approximately $90,000, was needed because of the company's expanding business in the St. Louis area. The company has also announced the election of James H. Binger as Vice-President and General Manager of the Belfield Valve Division, at Philadelphia.

RCA Service Company Appointments. Harry J. Mayer, former Manager of Technical Products Service of the Radio Corporation of America Service Company in the Chicago District, has been appointed New York District Manager of the Technical Products Service Division. Fred W. Wentker has taken over the post vacated by Mr. Mayer in Chicago, and William F. Hardman, former New York District Manager, has been made a special representative of the company in Washington, D. C.

Marlett Project Engineer for Kennametal. C. J. Marlett, representative for Kennametal, Inc., in the Chicago district during the past seven years, has been transferred to their Engineering Department at Latrobe, Pa., as Project Engineer.

Backus New Plant Manager for Mycalex. Alfred S. Backus, formerly Plant Superintendent of the Mycalex Corporation of America, has been promoted to the position of Plant Manager.

NEW PRODUCTS • •

New Coil Form. Greater inductive stability with unusually high Q has been obtained with winding directly metallized to the coil form instead of conventional wire winding. The new method, developed by the American Lava Corporation, fires a spiral metal coating on the ceramic, assuring intimate contact. The thin metal layer follows elastically the dimensional thermal changes of the ceramic which are far lower than those of any of the commonly used metal wires, and which are ideally suited for precision tuning circuits. To cite definite values: The inductance coefficient of AlSiMag 196 coil form, wound with copper wire, is 40 by 10^{-6} per degrees per Centigrade. For an identically shaped coil form of the same material, but with the metal fired on the ceramic, it is only 18 by 10^{-6} per degrees Centigrade. Any of the vitreous low loss AlSiMag compositions can be used for the coil form; selection of the material is governed by individual application. Hand test samples made to individual specifications can be furnished promptly and at reasonable cost. Further details can be secured from American Lava Corporation, Chattanooga, 5, Tenn.

Volt-Ohm-Mil-Ammeter. A new laboratory type volt-ohm-mil-ammeter with mirrored scales and greater accuracy made possible through the use of special one-half per cent resistors, has been developed by the Triplett Electrical Instrument Company, Bluffton, Ohio. Six d-c volt ranges from zero to 6,000, at 20,000 ohms per volt; six a-c volt ranges from zero to 6,000, at 5,000 ohms per volt. Five d-c ranges; decibels; output; and resistance ranges from zero to 100 megohms (compensated for greatest accuracy). The unit provides direct connections without cabling. Further data may be obtained from the company.

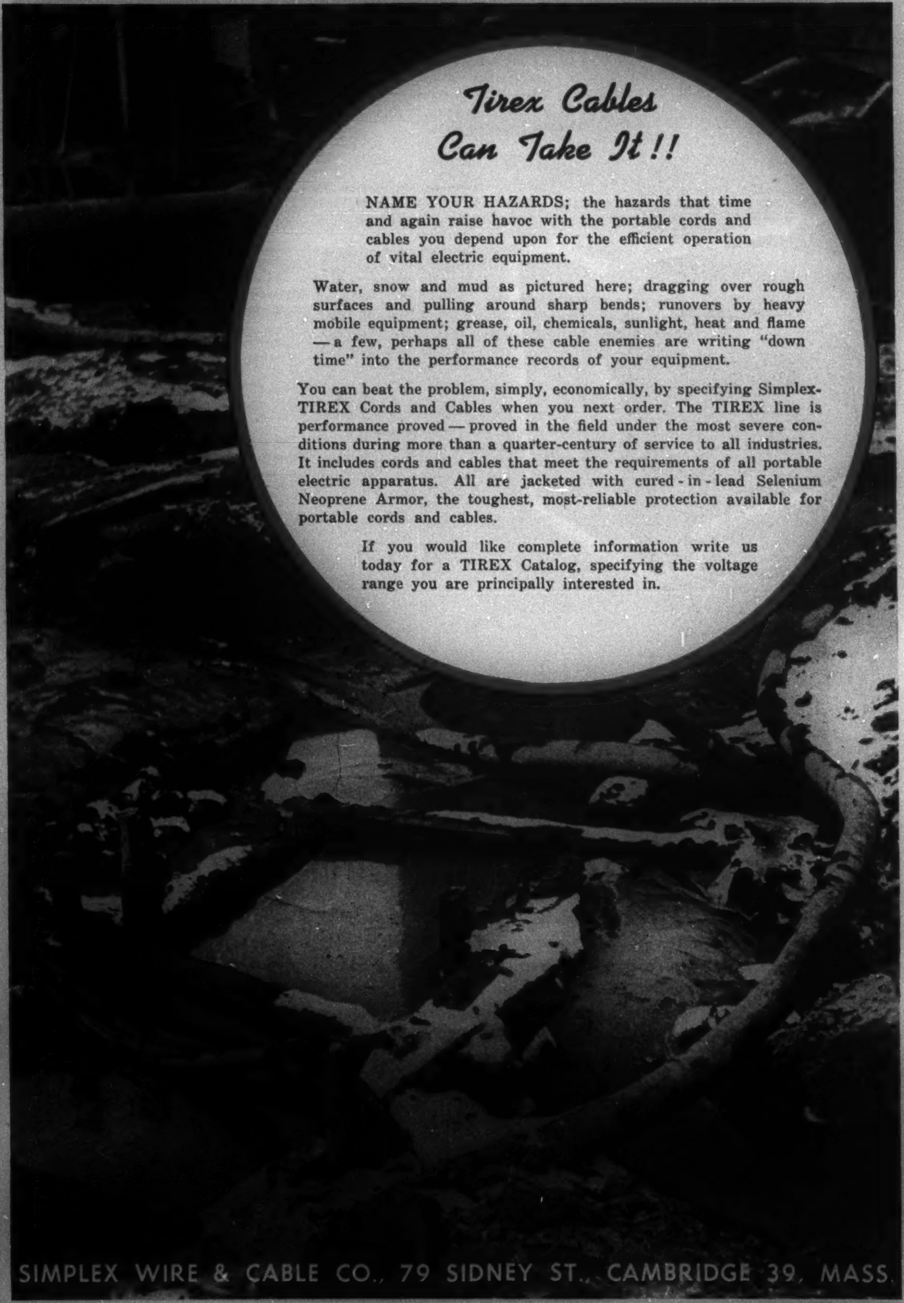
Radio-Frequency Waveform Monitor for Television. A radio-frequency waveform monitor, Du Mont Type *5034-A* has been designed for use in television broadcast installations to monitor the unrectified radio-frequency signal at the radio-frequency transmission line. The cathode-ray tube displays the radio-frequency carrier voltage on a linear time base at either field- or line-frequency. By adjusting the meter reading to full scale when a sync peak is positioned to reference line, the meter is calibrated to read any modulation level directly as percentage of peak signal. The monitor has a self-contained power supply; less than ten watts of peak radio-frequency power are required to produce peak to peak deflection. The Television Transmitter Division of Allen B. Du Mont Laboratories, Inc., Clifton, N. J., will furnish any additional information upon written request.

Polyethylene-Covered Aluminum Line Wire. Kaiser Aluminum and Chemical Sales, Inc., 1924 Broadway, Oakland 2, Calif., has announced the production of polyethylene-covered line wire, a new type of electrical conductor. Advantages of polyethylene covered aluminum are economy, light weight, strength, free stripping, no festooning, and easily handled long length. Further details may be obtained from the company.

Tiny Mike. A new line of miniature ceramic disc capacitors, identified as the Tiny Mike, has been launched by Cornell-Dubilier Electric Corporation. The Tiny Mike, 19/32 of an inch in diameter, and 5/32 of an inch thick, is designed for use principally in television, frequency modulation, and very-high-frequency applications; designed for bypass and coupling in assemblies that are very compact; and in various types of miniature electronic equipment. The capacitor is made in 500 volts direct current working at capacities of 100 micromicrofarads to 500 micromicrofarads at ±10 per cent or ±20 per cent; and in 1,000 to 5,000 micromicrofarads at guaranteed minimum capacity within an ambient temperature of between +10 degrees Centigrade and +65 degrees Centigrade. The Manufacturers' Division, Cornell-Dubilier Electric Corporation, South Plainfield, N. J., will furnish any other technical data on their new line of capacitors on request.

G-E Base-Ventilated Motor; New Type Electric Light. The General Electric Company has developed a modified base-

(Continued on page 34A)



Tirex Cables Can Take It!!

NAME YOUR HAZARDS; the hazards that time and again raise havoc with the portable cords and cables you depend upon for the efficient operation of vital electric equipment.

Water, snow and mud as pictured here; dragging over rough surfaces and pulling around sharp bends; runovers by heavy mobile equipment; grease, oil, chemicals, sunlight, heat and flame — a few, perhaps all of these cable enemies are writing "down time" into the performance records of your equipment.

You can beat the problem, simply, economically, by specifying Simplex-TIREX Cords and Cables when you next order. The TIREX line is performance proved — proved in the field under the most severe conditions during more than a quarter-century of service to all industries. It includes cords and cables that meet the requirements of all portable electric apparatus. All are jacketed with cured-in-lead Selenium Neoprene Armor, the toughest, most-reliable protection available for portable cords and cables.

If you would like complete information write us today for a TIREX Catalog, specifying the voltage range you are principally interested in.

SIMPLEX WIRE & CABLE CO., 79 SIDNEY ST., CAMBRIDGE 39, MASS.

Circutrol as a Resolver
Circutrol as a Phase Shifter
Circutrol as a Differential Unit
Double Phase-Shifter Circuit
Control-Synchro System
Resolver-Control System

For Electronic Computation

Kollsman Circutrol units offer a high degree of versatility as phase shifters, indicators and controllers. And when two or more are connected electrically, the solution of many complicated problems and functions is possible. These units are designed with high impedance windings to perform over a wide range of voltages and frequencies — characteristics that facilitate working them directly into any electronic circuit.

The Circutrol is but one of a complete line of miniature special-purpose AC motors engineered and manufactured by Kollsman Division, specialists for over twenty years in precision aircraft instrumentation and control. Each unit represents the solution to specific requirements. Among those available, you may find the exact answer to your control problems. If not, the experience and skill of Kollsman engineers may be called upon to produce units to your particular needs. For complete information, address: Kollsman Instrument Division, Square D Company, 80-74 45th Avenue, Elmhurst, N. Y.

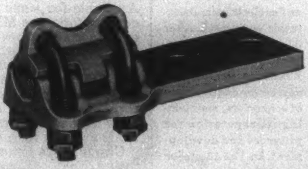
KOLLSMAN INSTRUMENT DIVISION

SQUARE D COMPANY

ELMHURST, NEW YORK GLENDALE, CALIFORNIA

GENERAL ELECTRIC CONNECTORS

will carry the full-load current of EITHER cable, tubing or rod



Disconnecting Switch Connector

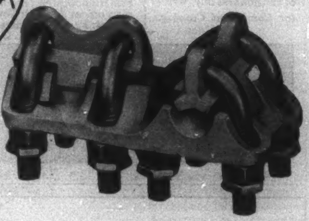
SIMPLIFY YOUR INVENTORY

Only ONE G-E power connector is needed for any one size of conductor used—cable, tube or rod. This alone reduces your inventory—and saves you money—because there's no need to stock different connectors for every type of conductor.

FEWER CONNECTORS NEEDED

General Electric connectors will handle a greater range of conductor sizes. For instance, five G-E terminal connectors (shown top, right) will handle ALL 22 conductor sizes between 1/0 and 1¼ IPS. How many different connectors do you have in stock to take care of this range of conductor sizes?

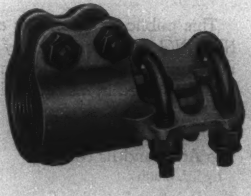
why not check this right away?



Station Tee Connector

SIMPLIFY ORDERING PROCEDURES

Each G-E connector has only *one* catalog number—and one price—regardless of the type of conductor for which it will be used. (And neither will you find two catalog numbers—and two prices—assigned to the same connector just because one is listed for use with tubing and the other for use with cable.) This will reduce your connector costs and simplify your ordering procedures by making it unnecessary to order several ordinary connectors when one G-E connector will do the job.



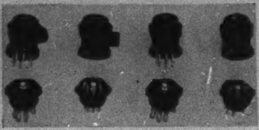
Power Breaker Connector

SAVE ORDERING TIME

With fewer connectors to order, you can order in less time. And G-E connectors are easier to order, too, for the simple reason that you don't have to specify so many different varieties to do the job.

Place an order today with your G-E sales representative and start realizing the many benefits to be gained by using General Electric connectors. Also, write for a copy of bulletin GEC-400 that contains 40 pages of valuable information on G-E connectors and see for yourself how easy they are to order. Write to *Apparatus Department, Section 856-53, General Electric Company, Schenectady 5, New York.*

GENERAL ELECTRIC



CANNON PLUGS

... standard components on fine electrical and electronic equipment. After *33 years* of building electrical specialties, Cannon Electric continues to pioneer new and better types of connectors, maintaining its reputation for progress and development. In the 13 *major type series* of connectors will be found most of the requirements for quick disconnection of electrical circuits. For a survey of the general line, write for *Condensed Catalog.*

"MR" MINIATURE TYPE CONNECTORS

Available for some time in a seven contact type, the MR Series is being expanded to include a three and also an eight contact fitting.

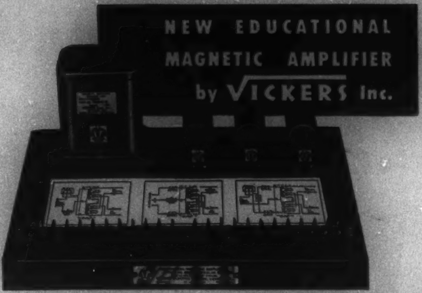
Plug shells are made of pliable rubber. Receptacle insulators are phenolic; mounting nut dural. Removable pressed fibre caps cover the solder ends of the contacts. Overall dimensions are less than one inch.

Capacity is 5 amperes; voltage rating 70 V.

The "MR" Series is particularly suited to instruments where power requirements are low and space limited.

Address Cannon Electric Development Co., Division Cannon Manufacturing Corporation, 3209 Humboldt St., Los Angeles 31, Calif. Canadian offices & plant: Toronto, Ontario. World export: Frazar & Hansen, San Francisco.

CANNON ELECTRIC



for School and Industrial Laboratories

- A unit designed by Vickers Electric Division to help students and industrial personnel obtain a wider knowledge of the characteristics and applications of high-performance self-saturating magnetic amplifiers.
- All three basic single-phase self-saturating circuits may be studied, and the educational unit can actually be used in operating controls circuits. Gives d-c or a-c output, uses d-c or a-c control power.
- Magnetic Amplifier Laboratory Manuals and Magnetic Amplifier Design Bulletins included with each educational unit.

Write for information and price.

VICKERS ELECTRIC DIVISION
VICKERS Inc.
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Elements of Nucleonics for Engineers

This publication contains a series of articles on nucleonics published in ELECTRICAL ENGINEERING and sponsored by the AIEE committee on nucleonics which was formed in 1946 in recognition of the very direct interest of the electrical engineer in the field of nuclear physics. Now combined in a single volume, the articles provide a convenient primer of nuclear theory.

CONTENTS

The Atom and Its Nucleus
by J. J. Smith
The Relation Between Energy and Mass
by Frederick Seitz, Jr.
The Nucleus—Its Structure and Reactions
by W. E. Shoupp and Hugh Odishaw
Nuclear Engineering
by E. U. Condon
Detection and Measurement of Nuclear Radiation
by G. Wesley Dunlap
The Separation of Isotopes
by G. Wesley Dunlap and R. M. Lichtenstein
Cascades Used in Isotope Separation
by Harold C. Urey
Nuclear Reactors—Some Basic Considerations
by F. L. Friedman
High-Energy Particle Accelerators
by J. R. Woodyard
Physical and Medical Aspects of Radiation
by L. L. German and H. M. Rozendaal
Nuclear Reactors for Power Generation
by Ward F. Davidson
Suggested Bibliography
Sources of further information

Copies of "Elements of Nucleonics for Engineers" are available at 80 cents each (40 cents to AIEE members) and may be obtained from the AIEE Order Department, 33 West 39th Street, New York 18, N. Y.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS New York, N. Y.
4-50

are coil failures costing you money?

look at this record!

18 failures in 8 years with regular insulation

Date and Cause of Failure

2/21/40	Armature coils grounded
12/29/40	Armature coils grounded
9/2/41	Open armature circuit
4/13/42	Armature coils grounded
4/18/42	Leads loose in commutator
10/24/42	Armature band thrown
4/5/43	Armature coils grounded
8/9/43	Open armature circuit
10/7/43	Armature coils grounded
9/30/44	Armature coils grounded
10/18/44	Armature coils grounded
7/28/45	Armature coils grounded
9/14/46	Armature coils grounded
2/6/47	Armature coils grounded
6/23/47	Armature coils grounded
9/17/47	Armature coils grounded
11/4/47	Armature band thrown
12/26/47	Armature coils grounded

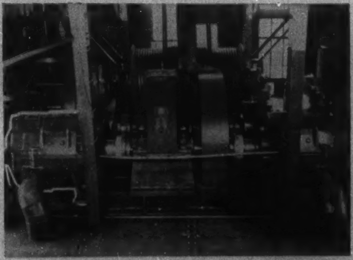
NOT 1 coil failure in 2 years with National special class H coils

"Still operating beautifully," is the report *two years after installation* on the National silicone-glass-mica armature coils of the motor shown above. They were installed January 7, 1948, in the National shop. That's quite a record, following the 18 failures in 8 years listed at the right above.

The motor is, of necessity, subjected to terrific abuse, since it is a hoist motor on a huge coal stripping shovel which often bites into solid rock. Excess heat burned out the coils monotonously . . . until National installed the special coils.

Special National Class H coils such as these are building up amazing records wherever high heat is a problem. They utilize silicone, melamine, glass, mica, MICA-CLAS, high-heat varnishes, special solders and other inorganic materials. The insulating materials are made in our plant to our rigid specifications. And all National coils fit snug and tight. They last.

Many armature burn-outs can be avoided by the use of higher grades of insulation. However, all-inorganic insulation isn't always the entire answer. Improved ventilation, better heat conductivity and other factors are also of importance. Your nearby National Field Engineer knows. Write for his name.



Part of the interior of the strip shovel is shown above. The motor outlined is the one which caused so much trouble and expense before National special Class H coils were installed. A larger view of the same motor is shown in the photo at the upper left.

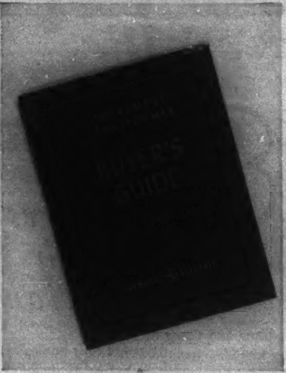
NATIONAL ELECTRIC COIL COMPANY

COLUMBUS 16, OHIO, U. S. A.

ELECTRICAL ENGINEERS: MAKERS OF ELECTRICAL COILS AND INSULATION— REDESIGNING AND REPAIRING OF ROTATING ELECTRICAL MACHINES

FOR EASY SELECTION of INSTRUMENT TRANSFORMERS

GET YOUR FREE COPY OF THIS NEW BOOK



For your convenience in ordering G-E's popular line of instrument transformers, the 1950 issue of the Instrument Transformer Buyer's Guide has just been published. It contains 82 illustrated pages of up-to-date information, including prices, ratings, and ASA accuracy classifications; covers both indoor and outdoor types. References are provided to help you order supplementary bulletins containing more detailed technical descriptions.

THE CONTENTS INCLUDE:

Potential Transformers
  Indoor
  Outdoor
  Fuses
Current Transformers
  Indoor
  Outdoor
Metering Outfits
Portable Transformers
  Potential
  Current
Ratio and Phase-Angle Tests
Mechanical and Thermal Limits of Current Transformers

If you use Instrument Transformers, you'll want to keep the Buyer's Guide handy. We'll be glad to send you a free copy. Just fill in the attached coupon.

Clip and Mail this Coupon Today

Section B604-24
Apparatus Department
General Electric Company
Schenectady, N. Y.

Please send me your bulletin, GEA-4626C, which describes the newest Instrument Transformers.

Bulletin needed for:
........Reference Purposes
... .Planning immediate project

NAME..
(Please print)
POSITION......................................
ADDRESS.......................................
CITY......................ZONE....STATE..........

GENERAL ELECTRIC

(Continued from page 28A)

ventilated motor, designed specifically for external applications such as driving power station auxiliaries mounted out-of-doors, where the totally enclosed fan-cooled units are not available. The motor is available in ratings from 200 to 3,000 horsepower and has been designed to be mounted on a concrete base which is raised sufficiently from the ground to allow contaminated ambient air to flow through the foundation at high velocity, as in a storm. Ventilating air enters the motor through a vertical passage in the base, and is pulled from the ambient air stream at low velocity, so that almost no water or foreign matter can be carried up into the motor. After circulating through the motor, the ventilating air is exhausted from the top. Exhaust ports are protected by an over-hanging metal shield and baffling. In case air enters these exhaust ports during a heavy storm, adequate elimination and drainage are provided, thus eliminating the duct work necessary to separate intake and exhaust vents when both are located in the base of the motor. Additional information on the new base-ventilated motor is contained in bulletin *GED-1232*, which is available from the General Electric Company at Schenectady 5, N. Y.

General Electric's Lamp Department has announced a new type of incandescent electric light, which has a unique inverted mushroom shape and an enamel finish to form a combined light source and fixture in one unit. The bulb is made in the 50-watt size, and the new form directs two-thirds of the bulb's light upward, creating an indirect lighting effect. Designated *50GA*, the bulb will be available in May. Further information may be secured from the company at Nela Park, Cleveland 12, Ohio.

Precision Pressure Switch. Precise level control of moderate heads of water or other liquids has been made possible without the use of floats by the development of the Soreng pressure switch, which may be set to operate on heads from six inches to 14 inches and to reset on heads as low as one and a half inches. The switch is unaffected by turbulence and mechanical vibration, and is furnished in two basic types—for fixed or variable levels. Actuating force is transmitted by a diaphragm and pressure plate to a single-pole double-throw snap-action switch rated at six amperes, 125 volts alternating current, inductive load. For full information, contact P. H. Korrell, Soreng Manufacturing Corporation, 9555 Eden Avenue, Schiller Park, Ill.

Westinghouse Developments. The Westinghouse Electric Corporation, P. O. Box 2099, Pittsburgh 30, Pa., has announced the following new products:

1. Type E industrial steam turbines with close-coupled, integral reduction gears for low-speed applications. Equipment such as pumps, fans, compressors, and generators can be driven at their proper speeds by these Gearturbines while the

(Continued on page 42A)

INDUSTRIAL APPLICATION of ELECTRON TUBES

Papers and discussions presented at the AIEE Conference on Industrial Application of Electron Tubes, Buffalo, N.Y., April 1949. Sponsored by the AIEE Subcommittee on Electron Tubes of the Electronic Committee and the Subcommittee on Electronic Control of the Industrial Control Committee, jointly with the AIEE Niagara Frontier Section.
Price: $3.50.

and

AUTOMATIC CONTOURING CONTROL of MACHINE TOOLS

Papers presented at the AIEE Conference on Automatic Contouring for Machine Tools held during the AIEE Midwest General Meeting, Milwaukee, Wis., October 1948. Sponsored by the Machine Tool Subcommittee of the AIEE General Industry Applications Committee. The papers cover mechanical, electric, and hydraulic contouring devices, and combinations of these types, as applied to machine tools.
Price: $4.00 ($2.50 to AIEE members).

Orders for these publications should be sent to:

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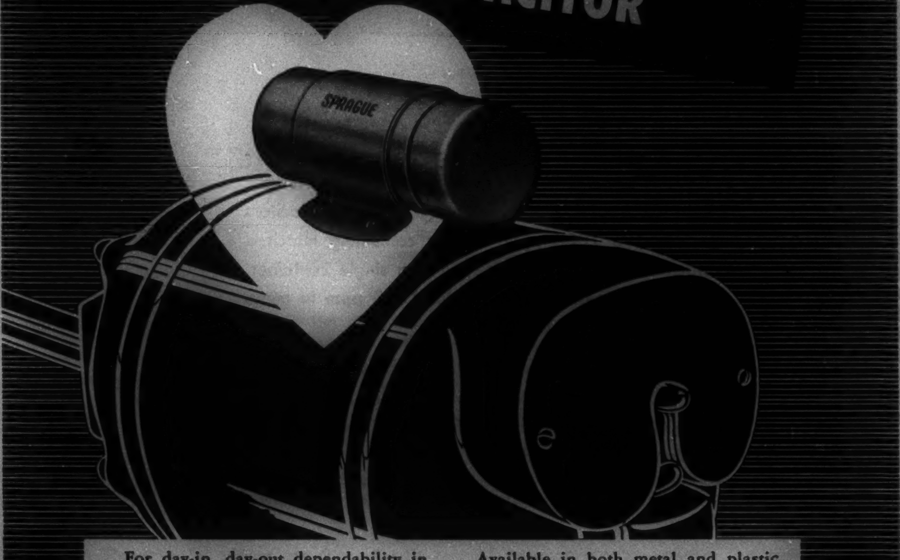
The HEART of the START is a SPRAGUE A-C MOTOR-STARTING CAPACITOR



For day-in, day-out dependability in hundreds of thousands of starts . . .

For outstanding reliability that spells freedom from costly service and consumer complaints on a-c motor-driven appliances and equipment . . . ***Specify Sprague A-C motor-starting capacitors!***

Available in both metal and plastic cases, with mounting hardware for any application. Capacitance ratings for motors as high as 7½ horsepower.

Sprague application engineers will be glad to assist you in analyzing specific capacitor problems.

Write for sample request form and catalog.

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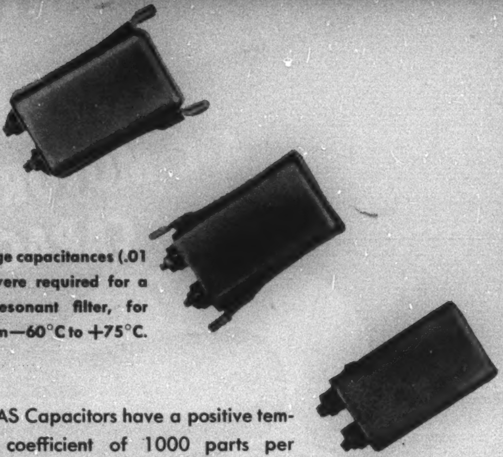
Another Engineer's Problem Solved*



SUBJECT: ZERO TEMPERATURE COEFFICIENT CAPACITORS

PROBLEM: Relatively large capacitances (.01 to .5 Mfd.) were required for a 400 cycle resonant filter, for operation from —60°C to +75°C.

SOLUTION: Plasticon AS Capacitors have a positive temperature coefficient of 1000 parts per million per degree Centigrade. Plasticon LS Capacitors are negative 1000 ppm/°C. By combining matched capacitor elements of each type in a single container, temperature coefficients from plus 1000 ppm to minus 1000 ppm/°C can be supplied.

A .25 mfd. capacitor for 440 VAC, 400 cycle operation Type (AL)SC254-44X measures 1 ¾" x 1" x 2⅛" high. Type (AL) Capacitors can be furnished from 330 VAC and higher; from .01 mfd. and up.

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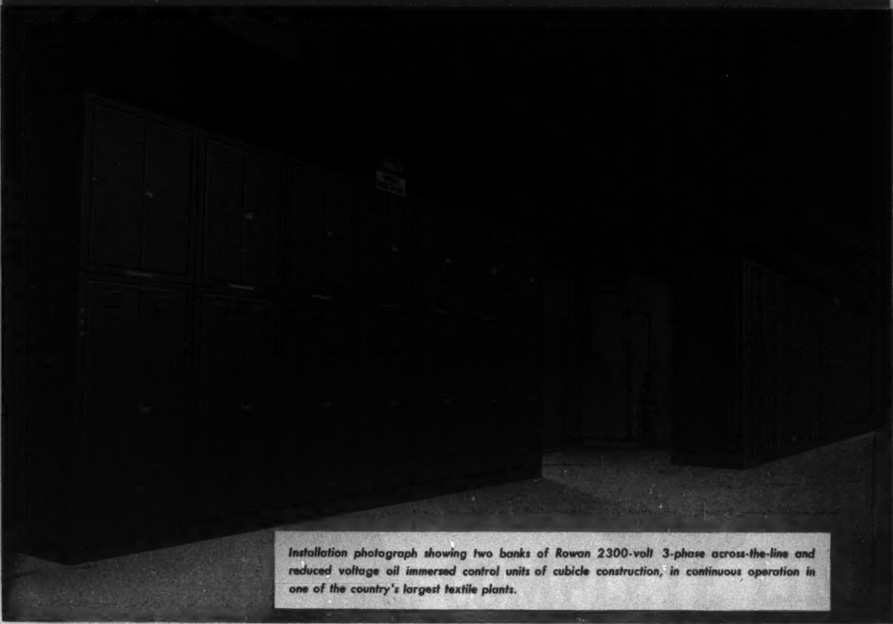

Installation photograph showing two banks of Rowan 2300-volt 3-phase across-the-line and reduced voltage oil immersed control units of cubicle construction, in continuous operation in one of the country's largest textile plants.

Rowan engineers have pioneered the design and manufacture of a self-contained, self-supporting, 2300-volt control unit for single or bank mounting dependent upon installation facilities and available for indoor or outdoor service.

Each standard unit consists of: a self-contained, insulated bus; a self-contained control potential transformer; current-limiting or high interrupting capacity fuses; a specially designed, quick-acting, heavy-duty contactor; seal-off motor lead compartment; magnetic overload relays with electric reset, instantaneous and inverse time element; centralized, low voltage control compartment and a self-contained, tank lowering device.

Many other added features are available, such as watt-hour meter, volt meter, ammeter, potential switch, etc.

Rowan sales offices are conveniently located throughout the country. A representative will be glad to call at your office to give you complete information.

ROWAN CONTROL

THE ROWAN CONTROLLER CO., BALTIMORE, MD.

BOTH CARRY 390 AMPS.

BUT ROCKBESTOS A.V.C.® IS 43% SMALLER

With higher-rated A.V.C. and a 390 ampere load INSTALLED COSTS ARE LOWER*—

- you use a 400 MCM cable *not* 700 MCM
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- you use *smaller* fittings and lugs
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Size for size A.V.C. has a HIGHER AMPERE RATING . . . Hi I . . . YOUR BEST BUY

Permanently-insulated Rockbestos A.V.C. can save you money. Write for the booklet "Cut Current Carrying Costs."

*Comparison with Type RH based on Chapter X—National Electrical Code, 40°C-104°F Ambient

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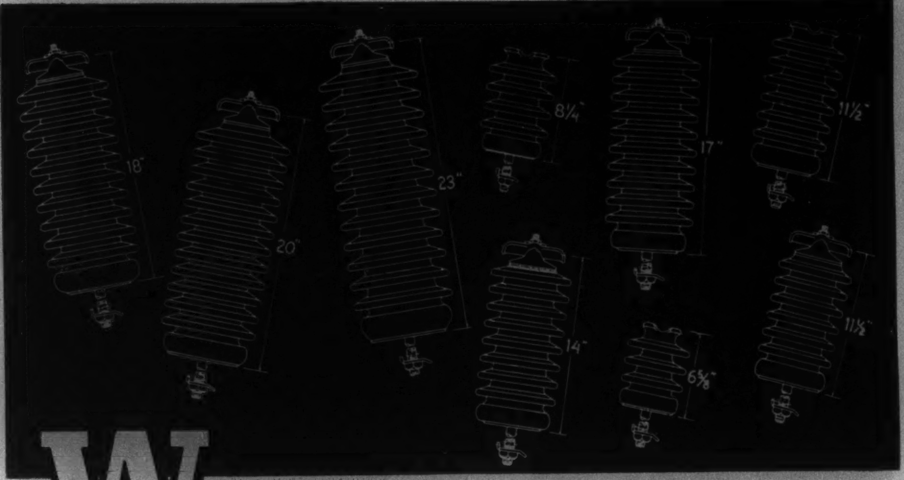

WHATEVER POST YOU NEED ...IT'S IN O-B's COMPLETE LINE

Post users will find in the O-B Catalog a complete range of line posts covering the entire requirements of both distribution and sub-transmission voltages, but this isn't the whole story. In the many years that O-B has manufactured posts, starting with the early days of this design, these insulators have had the unequalled advantage of O-B's research facilities directed toward obtaining the highest level of performance in this class of insulation. To improve promptness and volume of deliveries, a considerable portion of O-B's recent million-dollar plant expansion program was devoted largely to the most modern facilities to manufacture posts. Sound value is now backed by adequate supply of a line post that carries O-B's reputation for the finest in insulation--ready for your next line!

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Now Available!

MOLYBDENUM PERMALLOY POWDER CORES*

HIGH Q TOROIDS for use in Loading Coils, Filters, Broadband Carrier Systems and Networks—for frequencies up to 200 KC

COMPLETE LINE OF CORES TO MEET YOUR NEEDS

- ★ Furnished in four standard permeabilities—125, 60, 26 and 14.
- ★ Available in a wide range of sizes to obtain nominal inductances as high as 281 mh/1000 turns.
- ★ These toroidal cores are given various types of enamel and varnish finishes, some of which permit winding with heavy Formex insulated wire without supplementary insulation over the core.

For high Q in a small volume, characterized by low eddy current and hysteresis losses, ARNOLD Moly Permalloy Powder Toroidal Cores are commercially available to meet high standards of physical and electrical requirements. They provide constant permeability over a wide range of flux density. The 125 Mu cores are recommended for use up to 15 kc, 60 Mu at 10 to 50 kc, 26 Mu at 30 to 75 kc, and 14 Mu at 50 to 200 kc. Many of these cores may be furnished stabilized to provide constant permeability (±0.1%) over a specific temperature range.

** Manufactured under licensing arrangements with Western Electric Company.*

W&D 2930

THE ARNOLD ENGINEERING COMPANY

SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

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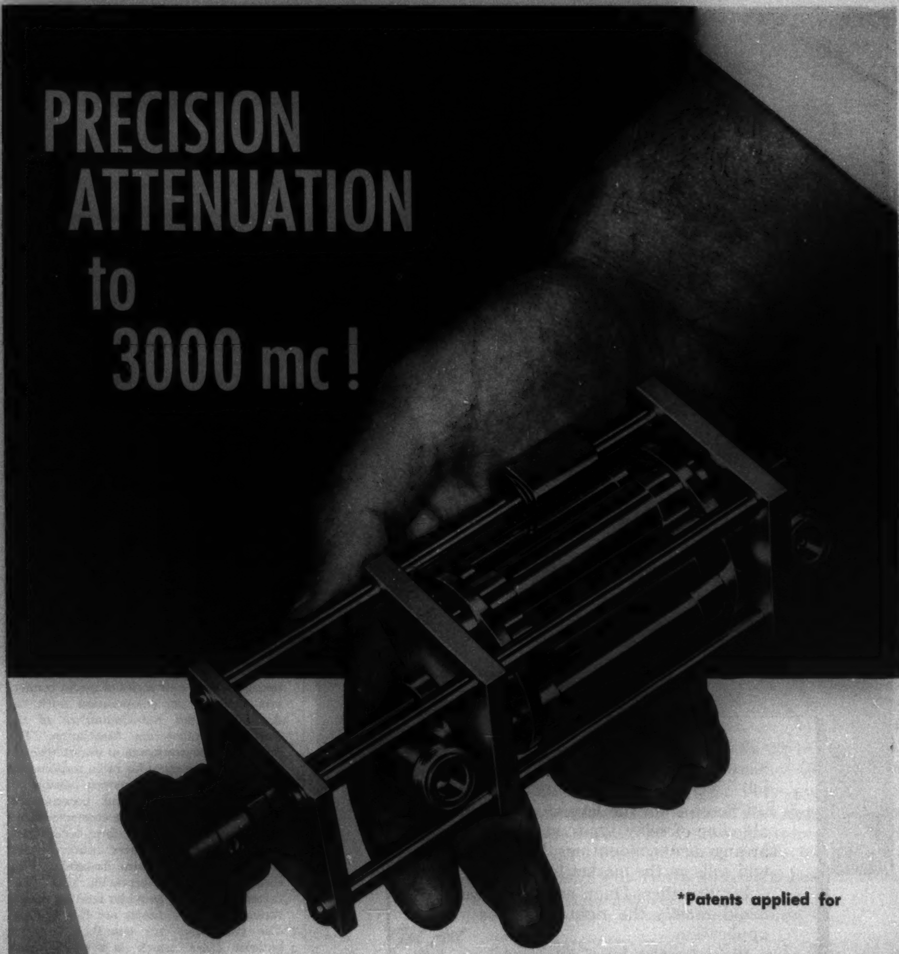
PRECISION ATTENUATION to 3000 mc!



*Patents applied for

- VSWR less than 1.2 at all frequencies to 3000 mc.
- Turret Attenuator* featuring "Pull—Turn—Push" action with 0, 10, 20, 30, 40, 50 DB steps.
- Accuracy ± .5 DB, no correction charts necessary.
- 50 ohm coaxial circuit. Type N connectors.

Inquiries are invited concerning single pads and turrets having other characteristics

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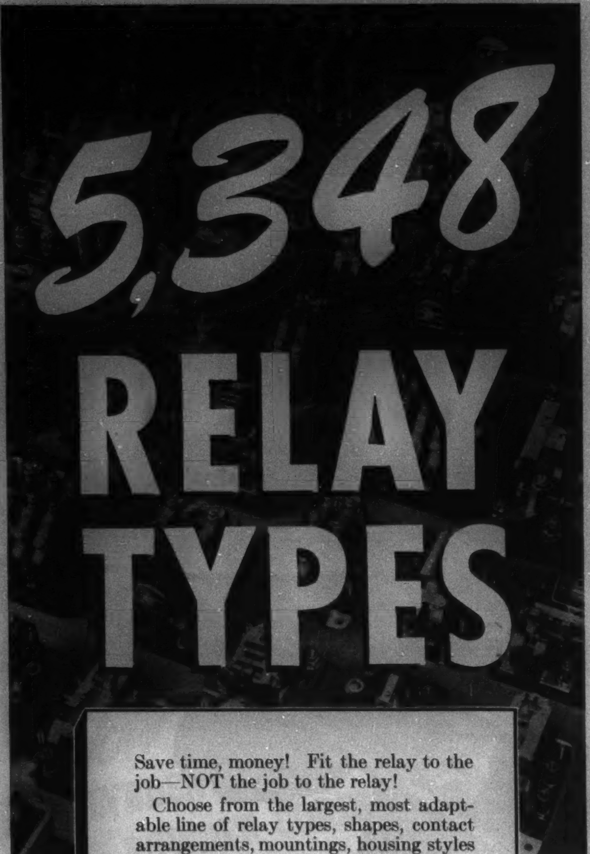
6644 SANTA MONICA BLVD., HOLLYWOOD 38, CALIFORNIA
Hillside 9294



Save time, money! Fit the relay to the job—NOT the job to the relay!

Choose from the largest, most adaptable line of relay types, shapes, contact arrangements, mountings, housing styles and coils on the market today.

Let Struthers-Dunn engineers recommend *exactly* the right relay for your application.

Write for Catalog G for a quick guide to the most widely used of Struthers-Dunn's 5,348 relay types.

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(*Continued from page 34A*)

turbines operate at their most efficient speed. They are available with standard gear reduction ratios for the best operating speeds of the usual types of loads.

2. Rural distribution transformers for operation on 25-kv multi-grounded systems, which make possible economical service to sparcely settled rural areas or an increase in capacity in existing heavily loaded rural systems. Coil grouping is low-high-low to give low impedance, and basic insulation level is 125 kv, full wave. Ratings are from 3 through 50 kva, single-phase, 60 cycles, 24,940 grounded Y to 14,400 to 120/240 volts with full-capacity taps at 13,800, 13,200 and 12,870 volts and a reduced-capacity tap at 12,540 volts.

3. Indoor type *MR* through-type current transformers for low-voltage metering indoors with or without thermal demand meters. The new transformers have a continuous current rating of 200 per cent while not exceeding a temperature rise of 55 degrees Centigrade. Accuracy is maintained over this entire current span so that only two current transformers—200- and 400-ampere ratings—are required to meter in the complete range from 10 to 800 amperes. No short-circuiting device is used since the open-circuit voltage under full load is only about 100 volts. Type *MR* transformers are for operation up to 600 volts with primary current ratings of 200 or 400 amperes to 5 amperes.

Further information on the above products is available by writing to the company.

Audio Connectors. Cannon Electric has brought out a new series of audio connectors designed in co-operation with the Audio Facilities Sub-Committee of the Radio Manufacturers Association. The object of their work was to standardize on connector equipment for radio stations and also to incorporate the newest possible refinements in design and construction. Named the *UA* series, the connectors consist of two plugs and four receptacles, carrying three 15-ampere contacts rated at 1,500 volts minimum flashover. Plug shells are steel, receptacles zinc. The flattened plug top provides positive polarization; socket contacts are full floating. The connectors are described fully in bulletin *UA-1*, which is available from the Cannon Electric Catalog Department, 3209 Humboldt Street, Los Angeles 31, Calif.

TRADE LITERATURE

Bibliography of Polarographic Literature. The Leeds and Northrup Company has prepared a new bibliography of scientific papers for those interested in polarographic analysis. 2208 references are listed in chronological order, covering a wide variety of applications for this analytical method. Articles listed encompass the period from the earliest preliminary investigations in 1903 up to the middle of 1949, and include all available

(*Continued on page 48A*)

ANOTHER VICTOR INSULATOR THAT SAVES AS IT SERVES

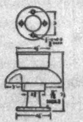
Left: VICTOR switch and bus insulators on a switching structure in the South.

Install VICTOR Switch and Bus Insulators and see how

TROUBLE-FREE PERFORMANCE REALLY PAYS OFF!

THE number of service-years built into any switch and bus insulator can be determined *only by actual performance data*—data obtained from *all* types of station installations subject to *all* kinds of conditions. And, because of their rugged, heavy-duty construction, that is where Victor switch and bus insulators rate *high!* Facts prove Victor switch and bus insulators *retain* their original high standards even after many years of severe service. This means *fewer* replacements and *lower* maintenance costs. Find out how much trouble-free performance can *save* you—*standardize* on Victor switch and bus insulators.

***Ready soon!** A new condensed Victor Catalog for handy reference. Write us now and reserve your copy.*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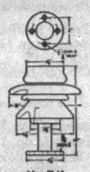
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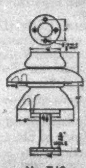
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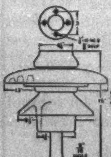
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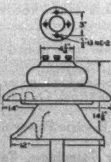
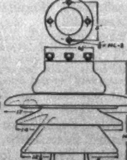
TR No. 10


No. 723
(2 unit stack)
TR No. 16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(stacking unit)
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Such discount is not applicable on extra copies unless ordered for other members.

1	General Principles Upon Which Temperature Limits are Based in the Rating of Electric Machines and Apparatus (June 1947)	$ 0.80
1B	Report on Guiding Principles for Specification of Service Conditions (May 1944)	.40
3	Guiding Principles for Selection of Reference Values for Electrical Standards (Oct. 1943)	.60
*4	Measurement of Test Voltage in Dielectric Tests (Nov. 1942) (ASA C68.1)	.80
*11	Rotating Electric Machinery on Railway Locomotives & Rail Cars & Trolley, Gasoline-Electric & Oil-Electric Coaches (Jan. 1943) (ASA C35.1)	.80
*15	Industrial Control Apparatus (Dec. 1943) (ASA C19.1)	.80
*16	Electric Railway Control Apparatus (Dec. 1931) (ASA C48)	.60
*17f	Mathematical Symbols (Jan. 1928) (ASA Z10f)	.40
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20A	Low-Voltage Air Circuit Breakers (Dec. 1946) (Published for trial use as a proposed revision of No. 20 No charge for copies)	
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32	Neutral Grounding Devices (May 1947)	.80
43	Recommended Practice for Testing Insulation Resistance of Rotating Machinery (Apr. 1950)	.60
40	Electric Recording Instruments (July 1947)	.60
45	Recommended Practice for Electric Installations on Shipboard (Dec. 1948)	3.50
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520	Test Code for Apparatus Noise Measurement (Mar. 1939)	.40
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*C8.16	Specifications for Rubber-Insulated Tree Wire (May 1940)	.60
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*C37.5	Methods for Determining the Rms Value of a Sinusoidal Current Wave and a Normal Frequency Recovery Voltage (1945)	
*C37.6	A Schedule of Preferred Ratings for Power Circuit Breakers (Jan. 1949) For those already possessing the 1945 edition of C37.4-.9, the January 1949 edition of C37.6 can be purchased separately for thirty-five cents ($.35) per copy.	
*C37.7	Operating Duty (Duty Cycle) for Standard and Reclosing Service (May 1945)	
*C37.8	Rated Control Voltages (May 1945)	
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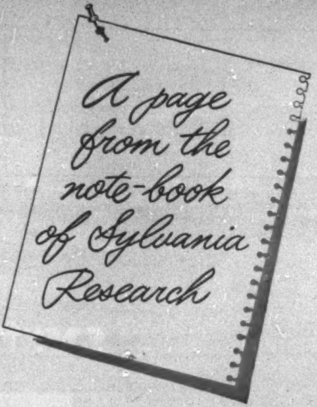
A page from the note-book of Sylvania Research

Automatic bulb sealing equipment speeds production of Sylvania Television Picture Tubes

It's a far cry from the slow and laborious "hand-work" methods of producing television picture tubes, to this automatic machine method now in operation at Sylvania's Ottawa, Ohio, plant.

On the machine shown here, the glass tube necks are perfectly sealed and bonded to the metal cones.

This process is but one important step in a completely conveyorized plant . . . where raw materials emerge as finished units. As a result of highly specialized mass production techniques and the application of the latest materials, Sylvania picture tube production increased by 30 percent during the past year.

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This means better product performance for you . . . better values for television set owners everywhere.

This shows Sylvania's modern rotary tube-sealing equipment in the process of bonding the glass necks to the tubes in the Company's plant at Ottawa, Ohio.

Advanced production engineering, scientific quality control, and precision fabrication of parts are factors behind the development of this automatic machine . . . a machine which is only one step in the efficient, mass production methods responsible for the manufacture of more, better and larger Sylvania television picture tubes.

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◀ Indoor switchboard is I-T-E type HV. Breakers are rated 1200 amperes continuous, 4160 volts, 150,000 KVA interrupting.

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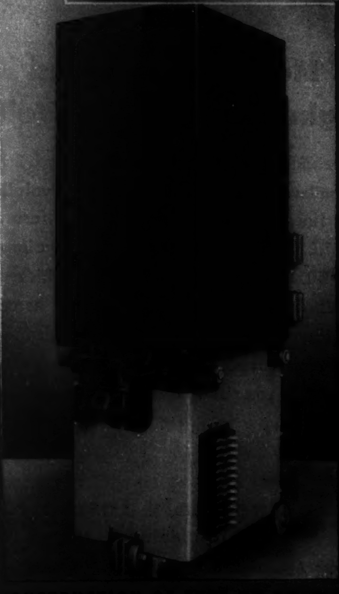

arranged and conform to the recognized codes specifying safe and accepted practice.

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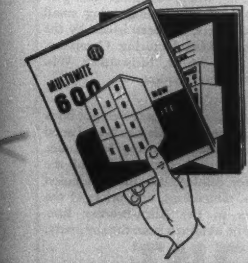

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On I-T-E 600 V Switchgear Assemblies: A complete reference guide, containing detailed information on Multumite construction, and helpful facts for specifying and ordering complete switchgear equipments. Ask for Bulletin 6003-D.

On I-T-E 5 KV Assemblies: Describes I-T-E's newest 5 KV Switchgear. Easy-to-read drawings and diagrams supplement photos and text. Ask for Bulletin 7000-A.

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• 1920 Thirty Years Service to the Electrical Industry 1950 •

(*Continued from page 42A*)

foreign and domestic sources. Papers are cross-indexed alphabetically by author and by subject matter. 1310 authors and 903 main subject classifications are included. Single copies of the bibliography, *E-90(1)* are available by writing to The Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia 44, Pa.

Tracerlab Catalog. Tracerlab, Inc., 130 High Street, Boston 10, Mass., has issued a catalog containing a complete listing of its nuclear instruments, facilities, purified and synthetic isotopes, safety devices, and consulting services for radioactivity applications. The booklet, catalog *B*, is available from the company upon written request.

Portable Cable Manual. A new 56-page manual on Hazacord flexible cords and portable cables has just been published by Hazard Insulated Wire Works Division of The Okonite Company. The manual contains complete technical information and dimensional data, covering the entire range from the smallest 300-volt type *SJO* cord to the largest 15,000-volt shovel cable. Tables of current carrying capacities, resistance values and their correction factors are shown. To obtain a copy of Hazard bulletin *H-420*, "Hazacord Flexible Cords and Portable Cables," write to the company at 72 Hazle Street, Wilkes-Barre, Pa.

Electrostatic Precipitation. The General Electric Company has issued a 16-page bulletin on electrostatic precipitation, designated as *GEA-5212*, which explains how electrostatic precipitation works, gives case histories of seven typical installations where the system is being used, and describes the various methods of electrostatic precipitation and the electric equipment applicable to each method. Copies are available from the General Electric Company, Schenectady 5, N. Y.

Small Power Transformers. A 28-page booklet, *61B6084A*, entitled "Small Power Transformers," which describes the procedures involved in manufacturing small power transformers, has been issued by the Allis-Chalmers Manufacturing Company, 931 South 70th Street, Milwaukee, Wis. It is available upon request.

Motor Control. A 76-page reference book on modern motor controls has been issued by the Allen-Bradley Company, Milwaukee 4, Wis. This, the fourth edition of the Allen-Bradley catalog, contains condensed information, dimensions, and prices of the many items in the Allen-Bradley line. Copies may be obtained from the company.

Laboratory Standards. The Measurements Corporation, producers of a precision line of laboratory standards designed for radio, television and other fields of electronic engineering, has issued a catalog, "Laboratory Standards," which contains complete specifications of some of their instruments. The catalog is available by writing to the corporation at Boonton, N. J.

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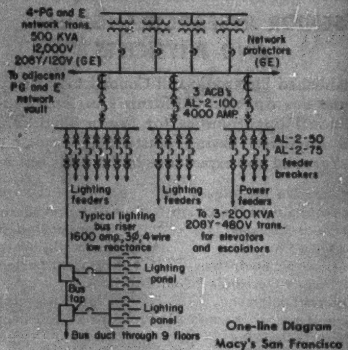
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Investigate today the many advantages of using General Electric switchgear in *your* plant for efficient, flexible power distribution. Contact your G-E sales representative for further information—and write for the helpful bulletins listed below. *Apparatus Department, General Electric Company, Schenectady 5, N. Y.*

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AIEE REPORTS

These publications are proposals for new standards or test codes, or revisions of present publications, which are in the formative stage. They are made available, *without cost*, so that all interested individuals may obtain them for study, and comment, thereby supplying practical experience in their use before submission for adoption.

20A	Low-Voltage Air Circuit Breakers (December 1946)
22A	Air Switches, Insulator Units, and Bus Supports (October 1949)
24	Protector Tubes (July 1940)
28A	Valve and Expulsion Type Lightning Arresters (February 1950)
50	Automatic Circuit Reclosers for A-C Distribution Systems (September 1949)
51	Guiding Principles for Dielectric Tests (September 1949)
502	Test Code for Single-Phase Motors (November 1941)
551	Master Test Code for Temperature Measurement (October 1948)
800	Test Code for Direct-Current Aircraft Machines (March 1947)

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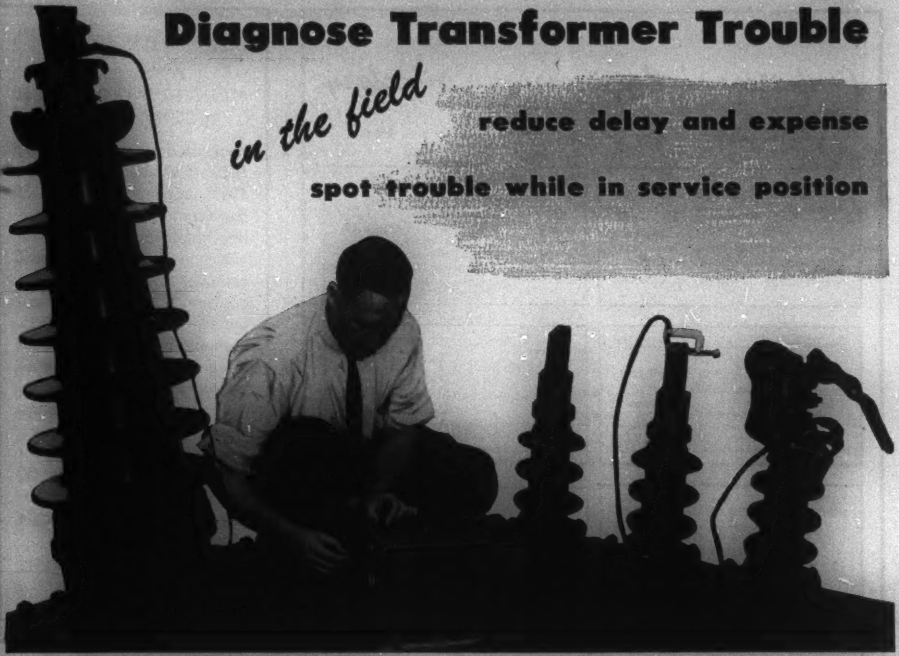

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It provides *for the first time* a portable device for measuring turn ratio with high precision.

It can be carried anywhere, to the top of large transformers, in the transformer shop or stock location.

With it you can:

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- Quickly identify leads and taps.
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Standard rubber insulation

TYPICAL TEST RESULTS ON RUBBER COMPOUNDS

The tabulation below lists representative values that have been obtained in actual tests of these rubber compounds.

PROPERTIES AND TESTS		REPRESENTATIVE TEST VALUES FOR VARIOUS COMPOUNDS						
		AMARINE —40	AMERZONE —0	AMERZONE —B	AMARINE —RWS	AMERITE	AMPEROX	AMERPRENE
BASIC TYPE OF INSULATION		Natural Rubber	Oil-base	Butyl Rubber	Synthetic Rubber	Commercial 30%	Heat-Resistant	Polychloroprene
MAX. REC. COPPER TEMP.		60°C	75°C	80°C	75°C	60°C	75°C	80°C
ELECTRICAL CHARACTERISTICS	Dielectric Constant (Spec. Ind. Cap.)	4.0	4.0	4.0	4.5	4.5	4.5	....
	Ins. Res. (K)	50,000	7,500	40,000	30,000	30,000	20,000	100
	Dielec. strength in volts per mil	450	350	300	400	400	350	200
PHYSICAL PROPERTIES	Tensile Strength in lbs. per sq. in.	2000	600	700	950	1000 Synth. 1500 Nat.	1000 Synth. 1800 Nat.	2000
	Elongation in 2"	450%	300%	400%	450%	500%	500%	500%
	Permanent set	¼"	½"	⅜"	⅜"	¼"	¼"	¼"
ACCELERATED AGING	Type of test	Geer Oven	Geer Oven	Geer Oven	Oxygen Bomb	Geer Oven	Oxygen Bomb	Geer Oven
	Temperature	70°C	80°C	100°C	80°C	70°C	80°C	80°C
	Hours	288	168	672	168	504	336	168
	% Original Tensile Strength	70%	80%	80%	80%	85%	80%	90%
MOISTURE RESISTANCE	Gain in wt. after 7 days immersion at 70°C (Mg. per sq. in.)	25	....	20 or less	15 or less	35	35	30-60
	Capacity increase after 4 weeks immersion at room temperature	15%	15%	15%	10%	15%	15%	....
	Stability Factor 40-80 volts per mil 2 weeks at 50°C	.5%	1.5%	1.0%	.8%	2.0%	3.5%	....
SPECIAL PROPERTIES		High Voltage and Submarine use	Meets IPCEA ozone test	Withstands .03 conc. 10 hours	For hot and moist locations	General purpose rubber insulation	General purpose rubber insulation	Resistant to oil, flame and ozone

As the test data vary considerably with different sizes of conductor and thicknesses of insulation, these identical results can not be guaranteed throughout the whole range of sizes and voltage ratings. Some specific constructions will test higher and others will test lower than the listed values. However, the above table indicates in general what may be expected of these compounds.

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ELEC ENGR, Registered; 30, married; desires oppor in Latin America; exper in elec util, indus des, constr and contracting; competent draftsman; speaks some Spanish. E-532.

ELEC ENGR, B.S.E.E., Feb. 1950, Univ. of New Hampshire; 24, married; some pwr exper; desires pos with future in pwr, prod or sales; location, east, midwest or foreign. E-533.

ELEC ENGR, recent grad, top quarter; majored in electronics, electromagnetic theory, radio engg; Eta Kappa Nu; 25, married; 3 yrs with A.A.F. as weather observer; part time and summer exper util, transformer banks, machine breakers, etc. Salary secondary. E-534.

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ENGINEERS. (a) Electrical Engineer, to assume project responsibility in the cooperative engineering of complex systems involving micro-wave radio and radar, electronic and hydraulic servo-mechanisms. (b) Electrical Engineer, M.S. preferred; B.S. plus experience acceptable. Investigate control and servo mechanism problems, using analytical approach, translating results into engineering requirements and design. General analytical and mathematical ability very useful. Minimum of four years experience. (c) Design Engineer, B.S.M.E. or E.E. Evaluate engineering design executed by other groups making recommendations on adequacy or need for improvement. Carry out certain design studies in the fields of ramjets, turbojets and rocket propulsion. Location, Maryland. Y-3177.

ELECTRICAL ENGINEER, young, with at least three to five years experience in relay engineering, electrical design of sub-stations, or who has had experience in switchgear or tap changing work. Some experience in the testing department of a utility company helpful. Must be willing to do some drafting work in connection with his design work. Salary, $4200–$4500 a year. Location, Pennsylvania. Y-3179.

ELECTRICAL OR ELECTRONIC ENGINEER, 30–35, graduate, with at least five years design and development experience on electrical and electro-mechanical instruments and control systems, to design and develop electrical indicating instruments in the aeronautical and industrial fields. Salary, $4500–$5000 a year. Location ,New Jersey. Y-3187(a).

ENGINEERS. (a) Designers with ten years experience in the design of industrial A.C. and D.C. motors in the range of 25–500 H.P. Should be able to act as section leader in evolving original designs applied to electrical requirements. (b) Designer, electrical graduate, with experience in industrial electronics design, particularly that applying to various sizes of electric motor control. Salaries open. Location, Wisconsin. Y-3261-R-6271.
RESEARCH ENGINEER, mechanical or electrical graduate, preferably with M.S. degree and five years experience on servo-mechanisms and components for research and development on government project at university. Salary, $4000–$6000 a year. Location, New York State. Y-3263.

SALES SERVICE ENGINEER, 32–40, graduate, preferably in communications or courses in electronics, with training in sales service, preferably shop, office and field, and field service work including installation and servicing of electronic and mechanical equipment. Responsibilities will include demonstrations in the field of electronic equipment to customers, instruction of customer personnel on operation, maintenance, etc., of electronic and hydraulic control equipment; servicing of the equipment and making field service reports. Traveling about 75% of the time. Salary open. Headquarters, Connecticut. Y-3276.

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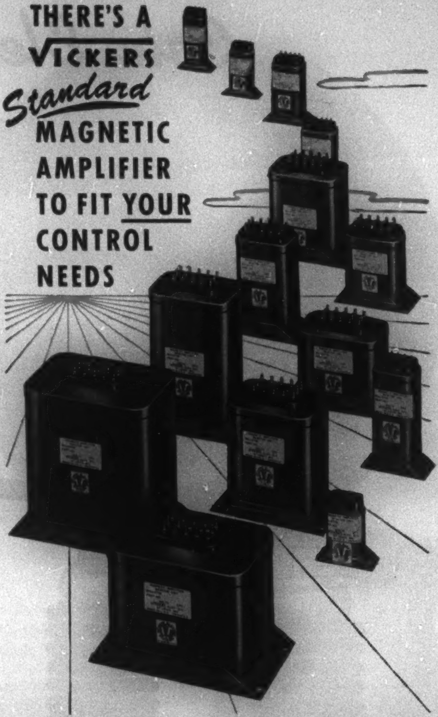

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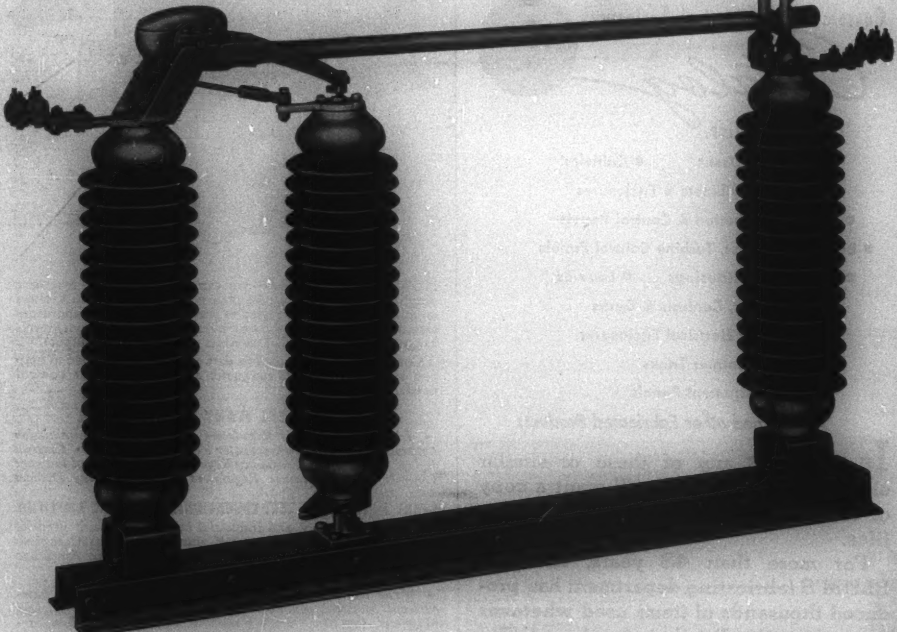

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RCA-5879 Sharp-Cutoff Pentode. Of the 9-pin miniature type, the 5879 is designed for a-f applications where reduced microphonics, noise, and hum are essential. It is especially useful in the input stages of medium-gain amplifiers.

RCA-5675 "Pencil-Type" Triode for UHF. Employs double-ended coaxial-electrode structure, for use in grounded-grid circuits. As a local oscillator, it will deliver 475 milliwatts at 1700 Mc. and about 50 milliwatts at 3000 Mc.

RCA-5794 Fixed-Tuned Oscillator Triode. Designed for Radiosonde Service, the 5794 employs two resonators integral with the tube. The output resonator is tuned to 1680 Mc. by means of an adjusting screw. The useful power output is in the order of 500 milliwatts.

For data on any of the tubes described above, write RCA, Commercial Engineering, Section D39R, Harrison, N. J.

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